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ELECTROMECHANICAL components & systems DESIGN

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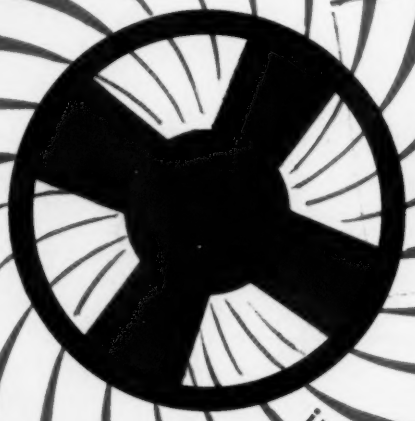

in this issue • components digest 19 • FANS AND BLOWERS

James Flora

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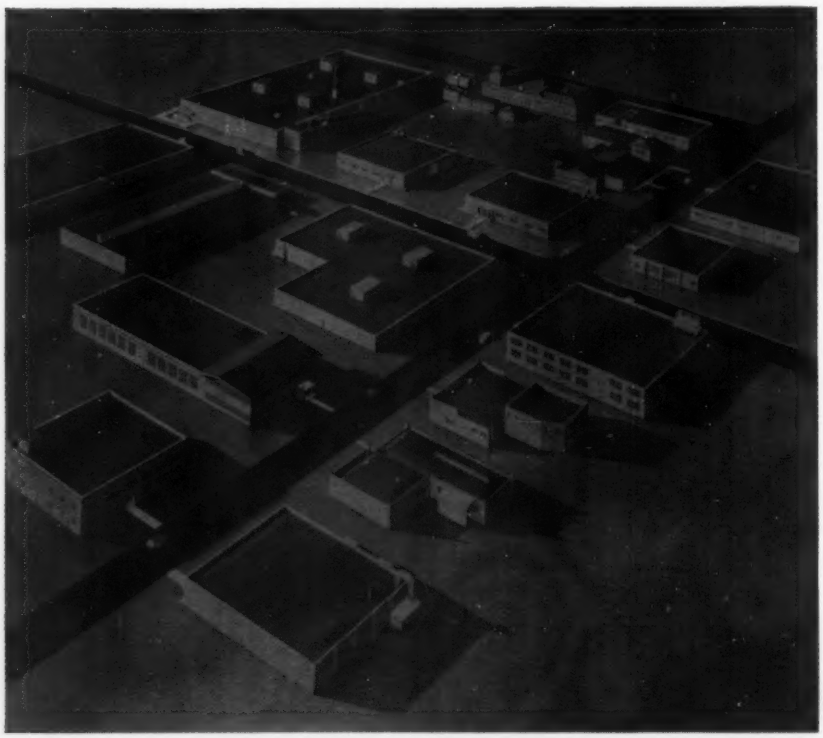

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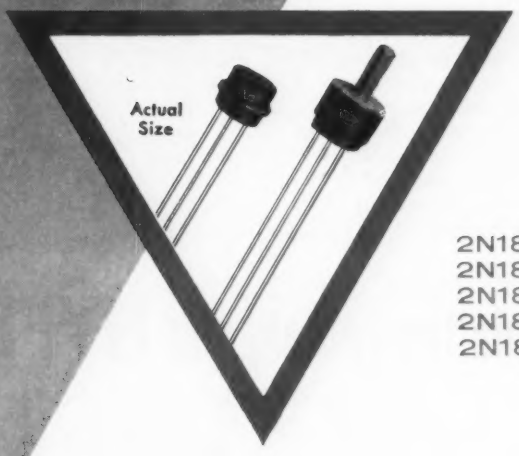

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				Min.	Max.
2N1881	30	1.0	2	.40	2.5
2N1882	60	1.0	2	.40	2.5
2N1883	100	1.0	2	.40	2.5
2N1884	150	1.0	2	.40	2.5
2N1885	200	1.0	2	.40	2.5

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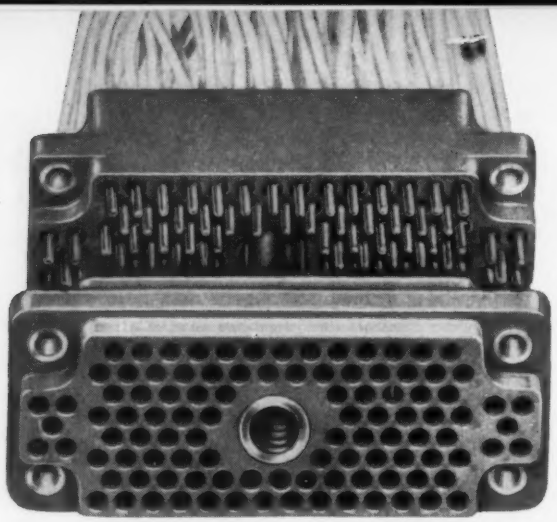

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ELECTROMECHANICAL components & systems DESIGN

The Sourcebook of Design Ideas in Applied Electromechanics

JANUARY 1961 • VOL. 5 NO. 1

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CIRCLE NO. 2 ON INQUIRY CARD

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design report
Information on Vernistat a.c. potentiometers for design engineers

VERNISTAT GENERATES A TRIG FUNCTION — CANCELS OUT A SERVO SYSTEM

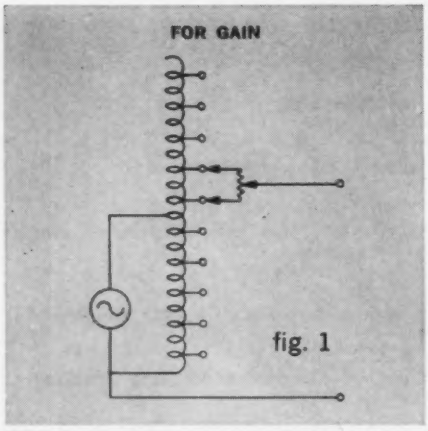

fig. 1

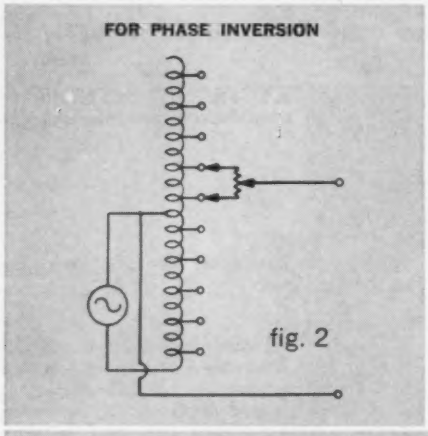

fig. 2

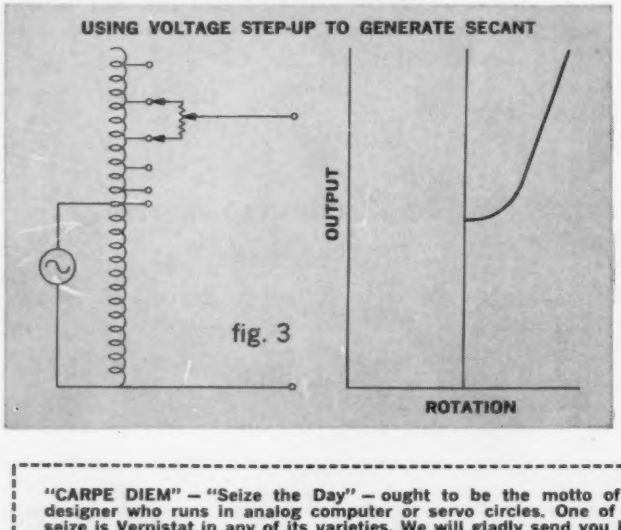

fig. 3

You get some interesting variants just by moving an input connection of the Vernistat from one end of the autotransformer to some other point. For example, you can use this set-up for voltage gain or phase reversal, as Figures 1 and 2 show.

If you play around with the spacing of the taps on the autotransformer, you get a nonlinear output. What's more, if you locate all the taps in the unexcited portion of the winding, the output voltage ratio will always be greater than 1 — a prime necessity for the secant curve.

This was observed by shrewd designers who were looking for a way to simplify a secant generator. It consisted of a servo amplifier, servomotor and resolver. The cosine winding of the resolver put out a feedback signal which was inverted in the servo so that a reciprocal secant voltage appeared at the output. All three units were replaced by a **single** Vernistat a.c. potentiometer modified as shown in Figure 3.

The step-up characteristic of the Vernistat can also be used to extend its output beyond the 0 to 100% rotation points **while maintaining slope and linearity.** "Extended Slope" Vernistats are useful wherever transients may cause overshoot of the potentiometer wiper. They are self-correcting and eliminate the need for accurately located and high-torque stops.

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For voltage-dividing, the Vernistat uses a toroidally-wound **autotransformer** over a tapewound magnetic core. Thirty-one precisely located taps are connected to a printed-circuit commutator, then the whole assembly is cast in epoxy resin. The commutator is heavily plated with rhodium to prevent wear, and all other contacts are made with precious metal alloys.

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CIRCLE NO. 4 ON INQUIRY CARD

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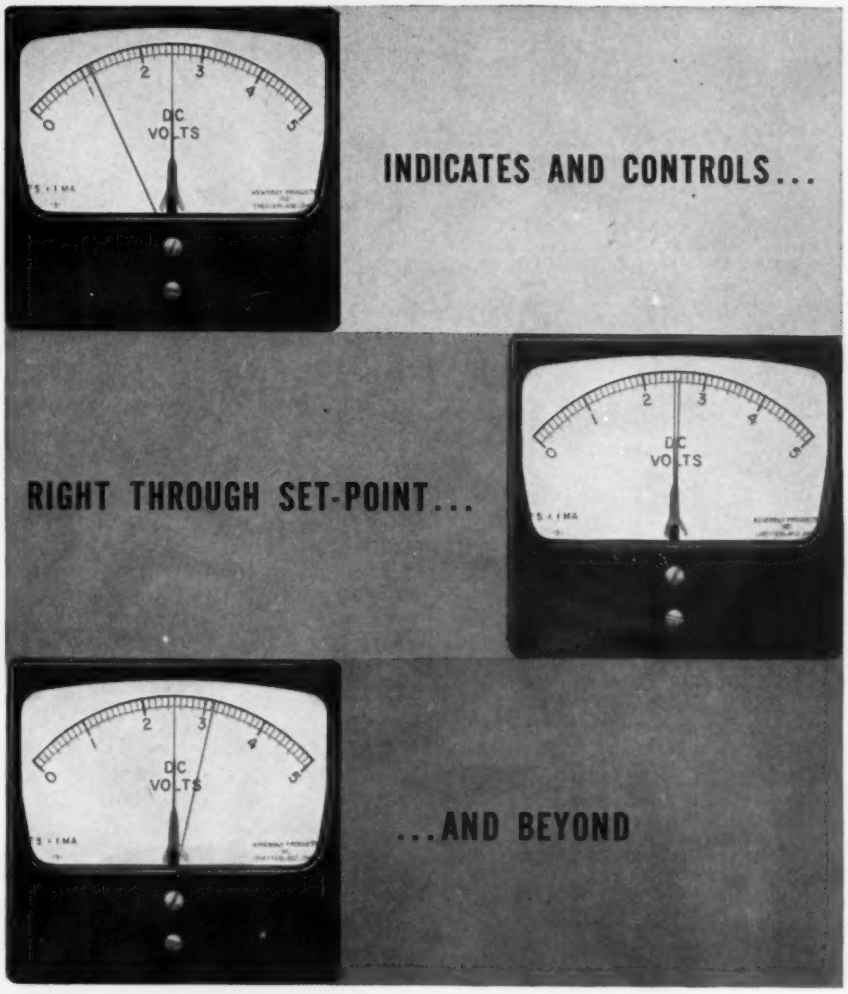

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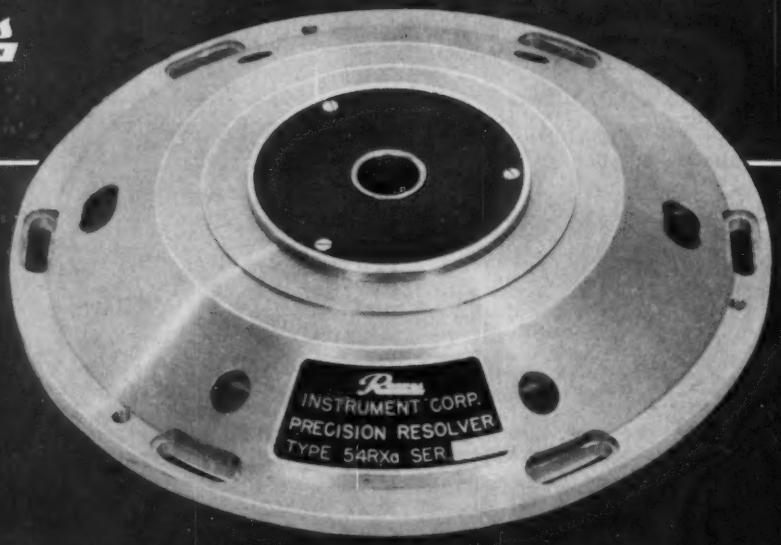

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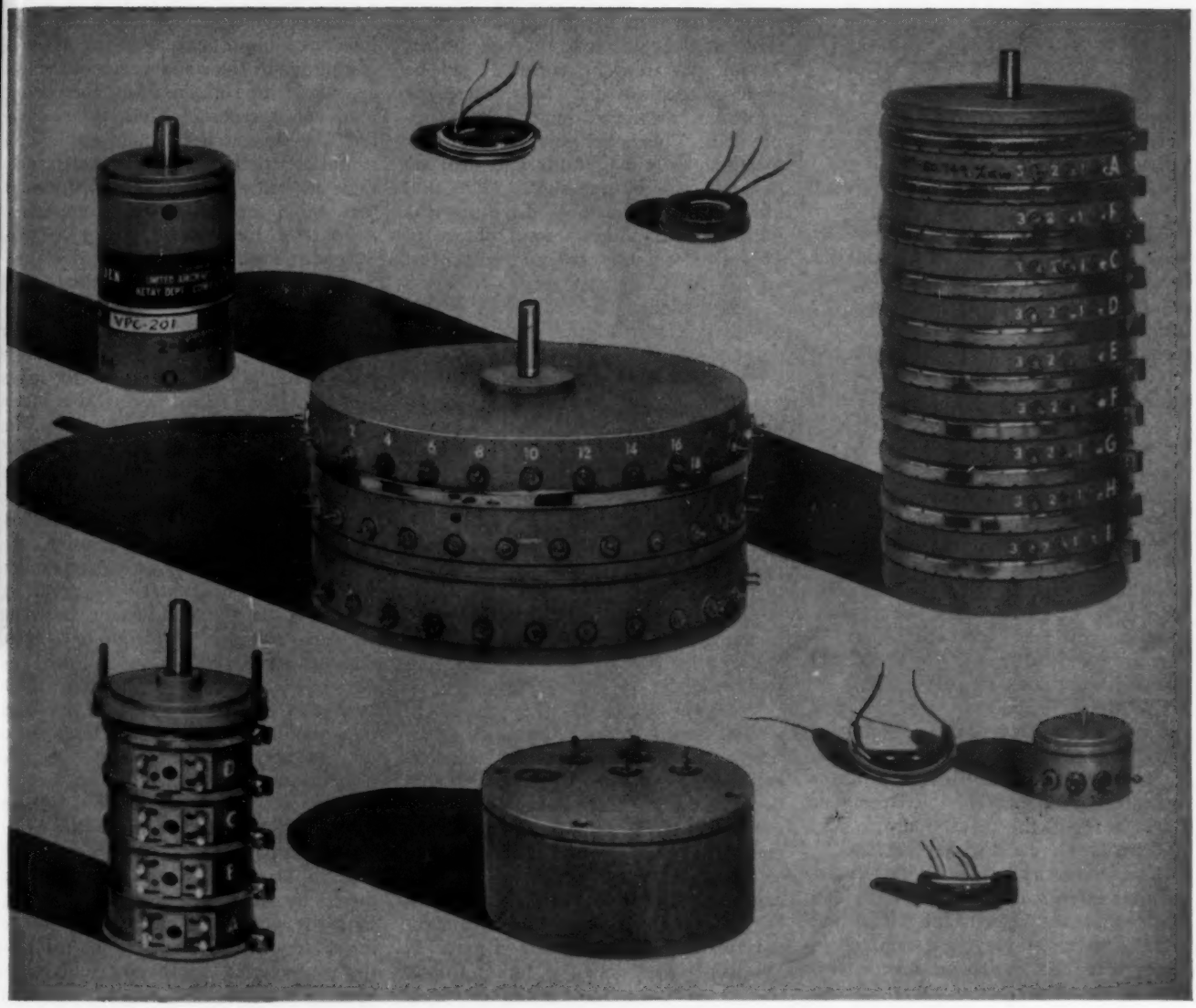

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LETTERS

More About Torque-to-Balance vs. Turn-Table Gyro Tests

The article "Inertial Gyro Test" in your November 1960 issue contains several misstatements of facts. First, the article gives the impression that the torque-to-balance test method is a new technique. As those familiar with the gyro test field are aware, this method has been in use for many years. During this time, it has not replaced the more expensive gyro test table methods for three principal reasons:

1. It does not test the gyro in the mode in which it is used, that is, slaved to a platform.
2. It can not measure drifts due to compliance effects.
3. It is at least 100 times less accurate than the test table method.

A very good discussion of the above points is contained in MIT Report L-105 entitled "Laboratory Testing of a Floated, Single-Degree-of-Freedom, Integrating Inertial Gyro." In addition, in an article entitled "Recent Progress in Inertial Guidance" in the December 1959 issue of the ARS Journal, Mr. William G. Denhard of MIT states:

"The laboratory has actual data showing that inferior caliber gyro units can pass tests made in constant-g field and yet fail those in varying-g field. . . . These tests are short and inexpensive but are unreliable indication for high caliber varying-g inertial performance."

As a general comment on the accuracy of the torque-to-balance method as used with the IRIG gyro of the Polaris Missile with reference to Figure 6 of your article, measuring errors come from the following sources:

1. Linearity and loading error of the 40 turn potentiometer at 800 cycles (estimated to be 0.01%).
2. Position error between potentiometer and digital readout.
3. A.C. power supply drift (0.1% long term).
4. Quadrature component of torquer current.

It will be noted that item 3, or a-c power supply drift, produces errors which are proportional to the square of the power supply drift as this power supply feeds both the control and reference winding of the microsyn torquer.

In reference to item 4, it is common practice to measure torquer current using a product resolver which eliminates effects due to quadrature current. Such a method is used by MIT as well as manufacturers of the IRIG gyro.

The sources of error listed for the servo table tests are much lower than those used in torque-to-balance testing. As no gyro torquer current need be used in accurate drift tests, there are no errors introduced due to power supply drift. This is the only accurate way in which drift magnitude and drift repeatable can be measured. The null uncertainty of the table drive servo is much less than one second of arc in properly designed test equipment. Most systems use integral control to bring the gyro gimbal to zero angle. Using the glass disc pick-off system, a peak reading position error of $\pm\frac{1}{2}$ second of arc over one revolution of the table has been obtained. System rate measuring accuracy of 0.001% has been available for a number of years.

Other small inconsistencies appear in your article. You mention a damping feedback path on page 26. Of course, any current supplied by means of this path is not indicated by the integrator readout and, therefore, will contribute to the system measuring error. Figure 2 shows this path connected but Figure 6 shows it disconnected during the operating mode.

From the above discussion, it is obvious that the torquer-to-balance measurements do not produce results identical to those obtained in servo drift rate tests, as the torque-to-balance measurements cannot sense gyro errors due to compliance effects and cannot sense errors as accurately as the gyro table can. The torque-to-balance method is, however, a valuable tool as a preliminary test in the manufacture of gyros. . .

James Colker
Assistant Chief Engineer
J. W. Fecker Div.
American Optical Co.

The detailed criticism in Mr. Colker's letter warranted a reply from Dynamic Research Corp., manufacturers of the Gyrotest station. Here are answering comments from DRC Technical Director A. L. Friedman. Ed.

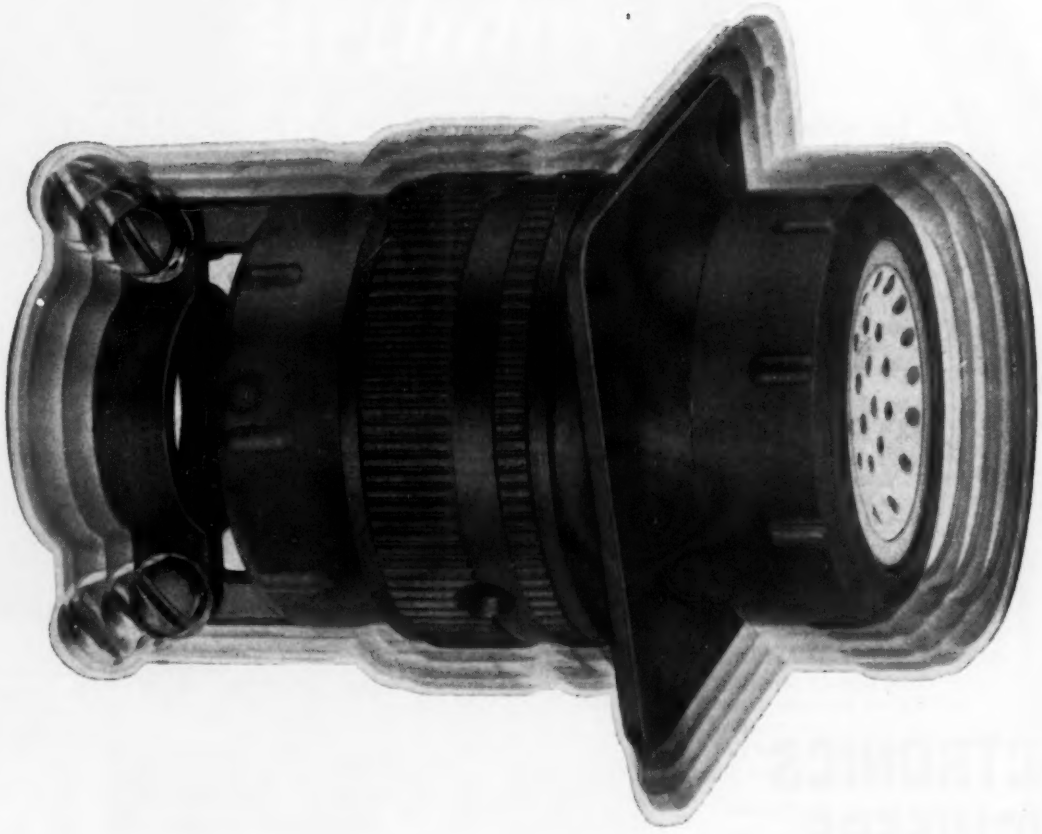
The purpose of the article "Inertial Gyro Test" was to review some aspects of the state of the art of inertial gyro testing and to report on Dynamic Research Corporation's Gyrotest TF-76 which, to our knowledge, is the first torque-to-balance station commercially available. The article did not intend to give the impression the torque-to-balance method of testing is new. It was, however, considered timely because it was based on a recent experimental study which showed that inertial gyros with accurate torquing capabilities have equivalent numerical drift rate under the two test methods.

To some extent, your general criticisms numbered 1 and 3 are redundant since whether or not a gyro is tested in the mode in which it is used is of incidental importance if the method of testing yields the same numerical values as would be obtained in the actual mode of operation. Thus, whether or not the torque-to-balance method is useful is strictly a function of its accuracy in comparison with platform or turn table methods. This comparison is more a function of the gyro performance itself and the desired experimental data than it is of the method of gyro testing.

In the case of the 25 IRIG gyro, for example, a series of comparative tests were made at MIT in which the gyro was alternately tested in the table mode and in the torque-to-balance mode. The results of this series of tests showed that it was impossible to distinguish the measurements made on the turn-table from those made by the torque-to-balance method. More specifically, the differences between measurements made on the turn table were as great or greater than the differences between the turn-table and the torque-to-balance measurements. It should also be pointed out the gyro used in these tests was one of the best of its kind manufactured at MIT. The test results do not actually indicate the relative errors between the methods of torque-to-balance and turn-table testing. Rather, they indicate that the drift variations in the gyro itself were significantly larger than the errors introduced by either test method. For any gyro for which this is true, it is of no importance which method is used in the engineering sense; the choice of method can be made on the basis of economic considerations. If the gyro tested had had a performance one order of magnitude better than the instrument tested, and if long term averaged drift rate measurements had been desired, then the turn-table method would probably have proved to be superior. Even in the case of the superior gyro, however, if short term drift measurements had been desired, for example 10 second average drift rate values, then the torque-to-balance method would probably still have been preferable.

In this same vein it should be pointed out that accuracy of turn-table measurements in general is a function of the amount of averaging desired in the measurement. For example, using the one-half second of arc pick-off error which you quote, a period of time equal to 3,000 seconds would be necessary to obtain a 0.001% measurement accuracy out of one earth rate. Thus, for measurement of parameters in cases such as the testing of gyros for ballistic missile applications the torque-

(Continued on page 83)



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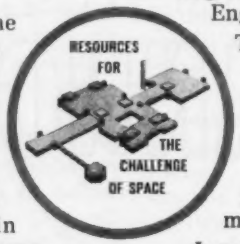

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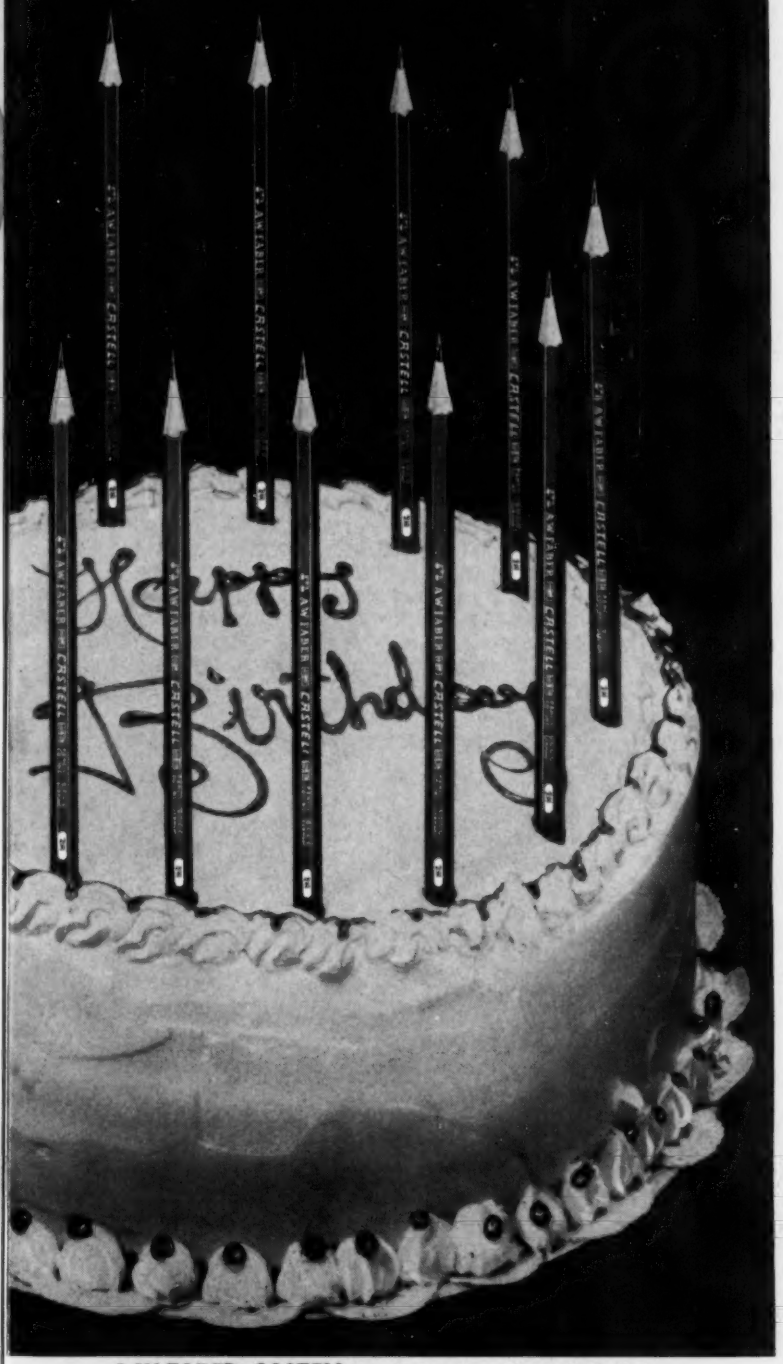

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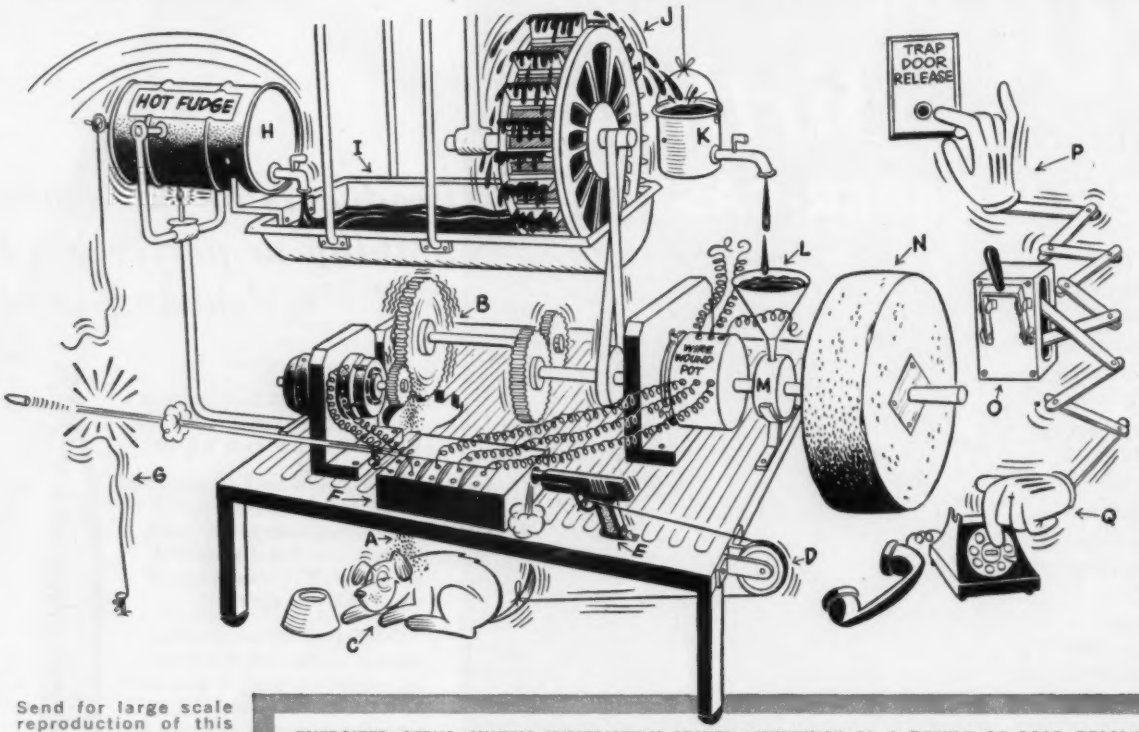

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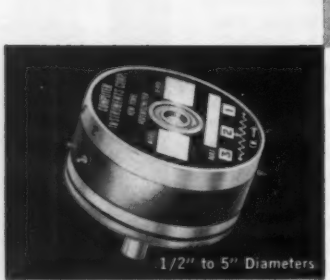

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CONTRACTS

"**Design Criteria for Automatic Test and Checkout Systems**", a study undertaken by the Motorola Military Electronics Div. and Douglas Missiles & Space Systems Engrg. Dept., under Air Force direction, has the following principal objectives:

- Validate the operational and maintenance requirements for test and check-out across the spectrum of future Air Force weapon systems for the period ending in the year 1975.
- Corroborate design criteria which will provide a logical basis for insuring compatibility of future weapon systems and their associated test and check-out equipment.
- Determine the feasibility of standardizing components of test and check-out equipment and the methodolgies of test and check-out for future weapon systems.
- Determine the feasibility of designing an integrated multi-purpose automatic test and check-out system or family of systems.

Anticipated effects of new design concepts such as integrated, or micro-electronic, circuitry and systems, which may significantly modify current practices and functions in the test and check-out system area will be one main consideration.

Using specially-developed fuel cells, Ionics, Inc., Cambridge, Mass. will investigate improved methods of generating electric power directly from common fuel gases. The U. S. Army Corps of Engineers awarded the contract. In addition to testing various fuel cell components, Ionics' engineers will build a small working unit which will demonstrate actual operating characteristics. Cells using solid electrolytes or ion exchange membranes will be explored.

Development of a manipulator system to be used in remote handling of rocket fuels and rocket motors is underway at the Mechanical Division of General Mills, under a contract from the Dow Chemical Co. of Midland, Mich. Because of the sensitive and highly explosive nature of chemicals used in the solid propellants, it is essential that all handling operations be performed remotely with personnel safely behind protective barricades. In a typical test, the propellant might be poured into a motor casing and cured at slightly elevated temperatures. A rocket nozzle then would be attached to one end of the casing and an igniter to the other. These operations would be accomplished within a test cell – all by remote control. The assembled motor must then be transported to the test firing area and attached securely to a test stand. These operations also will be performed by the manipulator system.

BRIEFLY:

Pressure transducers: $115,000 to Giannini Controls Corp. from Western Electric Co.

Molecular electronics: $2,300,000 to Westinghouse Electric Corp., from the U. S. Air Force.

Central air data system: $2,600,000 to the Garrett Corp. AiResearch Mfg. Div., Los Angeles, Calif. from N.A.A. Inc.

Fuzing mechanisms: $1,500,000 to ITT's Federal Div., Fort Wayne, Ind., for the Navy's Terrier missile.

Eagle missile system: $26,000,000 (in addition to previous contracts) to the Bendix Corp., Ann Arbor, Mich., from the Navy.

Airborne recording equipment: $2,000,000 to Melpar, Inc., Falls Church, Va., from Convair.

Falcon guided missiles: $65,000,000 to Hughes Aircraft Co., Culver City, Calif. from U. S. Air Force.

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HALL-EFFECT GENERATORS

For Solid State Synchros And Resolvers

Sigmund Harac, Project Manager

Oscar Tischler, Project Engineer

KEARFOTT DIVISION OF GENERAL PRECISION, INC.

In our June 1960 issue we reported that Kearfott was working on Hall-effect devices. Here is a report on what has developed to date, plus detailed information on the Hall-effect generators that are used in these devices.

In development of an Automatic Resolver Test Console for the Frankford Arsenal, Kearfott Division of General Precision, Inc. needed a new type of resolver to serve as the master. Specified performance requirements of quardature voltage tests and functional accuracy to 0.005% at both 60 and 400 cycles precluded use of available wound resolvers.

This problem provided Kearfott with the chief motivation to carry out their program for development of solid state resolvers based on the Hall effect. Results of the program indicate the Hall-effect resolver will not only have the required performance, but will also operate over a wide range of frequencies, and have advantages of smaller size, reduced cost, greater reliability, and absence of generator action.

HALL-EFFECT RESOLVER

The resolver consists of a pair of Hall-effect generators mounted with a 90° displacement in a uniform magnetic field. As shown in Figure 1, each generator has a pair of control leads for injection of control current, and output leads for Hall voltage output. This output voltage is proportional to the vector product of the control current and the magnetic field strength. When the generator is parallel to the magnetic field lines, the output is minimum; when it is at right angles to the magnetic field, the output is maximum; and there are sinusoidal variations in between. Thus, as the Hall-effect generators are rotated on a shaft, one of them generates a sinusoidal output corresponding in amplitude to the shaft position, while the other generates a cosinusoidal output. The field structure supplies a uniform, constant, dc magnetic field. The control current is maintained constant and its frequency determines the Hall output frequency.

Figure 2 shows the laboratory set-up. The generators are clamped on the shaft of an index stand and rotated between the pole faces of an electromagnet. Under actual operation, a permanent magnet could be used to supply the field. And further, if the magnet were rotated about a fixed pair of generators, equivalent output to the laboratory set-up would be obtained without the use of slip rings and brushes.

It can be seen from the above considerations that the development of a complete line of solid state synchros also becomes practical. Such a program is, in fact, currently under way at Kearfott for the Bureau of Naval Weapons.

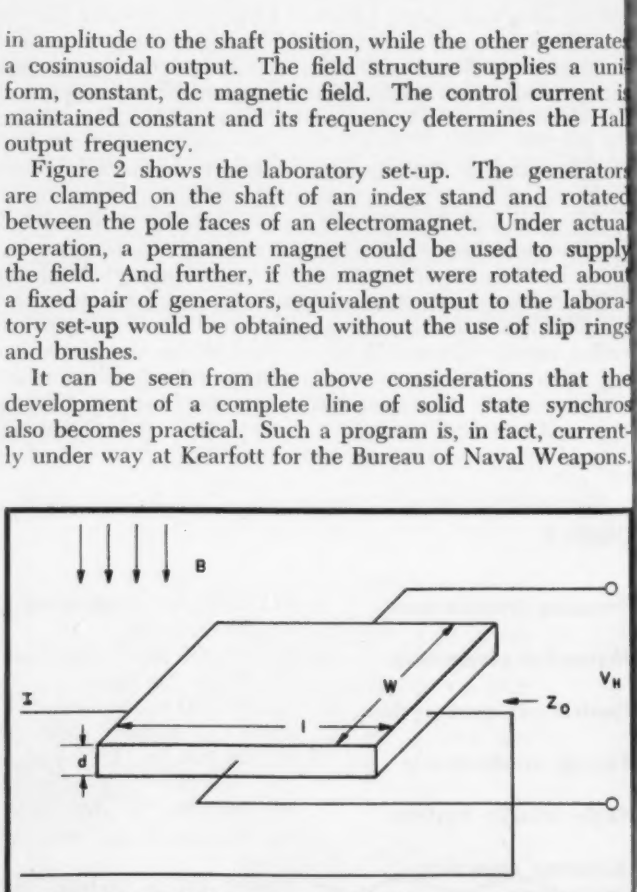


Fig 1 Schematic diagram of a Hall-effect generator, showing control leads for injection of control current, and output leads for Hall voltage output.

YSTAL MATERIAL

This report deals in general with Hall-effect generators use in solid state components and in particular with e ultra-precision resolver master. Spelling out the ultimate e of the component is important because such use has profound effect on the selection of the crystal material. e high precision resolver is used as a device that delivers specified voltage characteristic to be fed into a high put impedance amplifier. It will be seen that the optimum miconductor material for such an application is probably rmanium or silicon. This is not the case if the device expected to deliver power, such as when utilized in a ain of synchros. (See I. M. Ross, Journal of Scientific struments, 34, 12, pp. 479-484.)

An examination was made of commercially available all-effect generators for use in the solid state resolver. hese generators incorporate crystals of indium antimonide, dium arsenide, and indium arsenide phosphide; in some spects, they were suitable for this application, while in hers they were not. However, the Hall output voltages ere generally of sufficient amplitude, being on the order 300 millivolts. Increased outputs were possible by mbining several generators or by feeding the outputs into n amplifying circuit. Although higher outputs could be btained by resorting to different semiconductor materials, is particular parameter was not considered a limitation the commercial units. No evidence of quadrature components was noted, and the operation of the commercial nits was essentially the same over a frequency range from c to 5 kc. The output impedances, approximately 1 ohm less, were entirely satisfactory.

Areas in which commercial generators were found deficient were functional accuracy, temperature stability, and magnetoresistance effect. Functional accuracy tests performed with the commercial units revealed values comparable to those obtained with the standard line of resolvers but not the outstanding values required for the resolver master. One of the primary limiting factors was the zero-field, or misalignment, voltage. Because of magnetoresistance, this voltage varies in amplitude as the generator is rotated in the magnetic field. Various cancellation circuits were investigated to minimize the zero-field voltage effect at all positions, but it was found that these efforts would not produce satisfactory results until the basic zero-field voltage could be further reduced.

Temperature stability of the commercial generators represented another area that required improvement. Variations were noted in the Hall output and internal impedance values, resulting from internal heating as well as from changes in ambient temperature conditions.

The internal crystal impedances were also variable as a function of the position of the generator within the magnetic field. This magnetoresistance effect resulted in variations in output and input impedances of 20% to 60%, and was accompanied by proportionate changes in input control current which contributed further to functional inaccuracy. On the basis of these considerations, a program was initiated to produce special Hall-effect generators for application to the solid state resolver.

SPECIAL HALL-EFFECT GENERATORS

Investigation of the various semiconductor materials was conducted based on the following equations for the Hall effect.

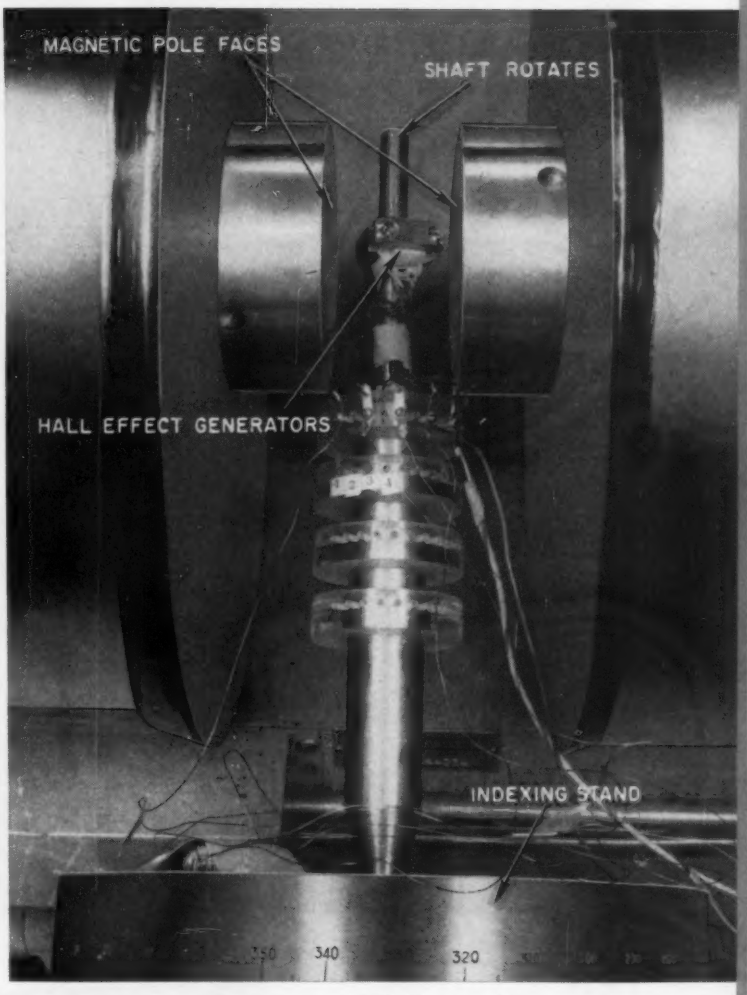


Fig 2 Laboratory set-up of Hall-effect resolver.

$$V_H = \frac{3\pi}{8}\left(\frac{1}{qn}\right)\left(\frac{BI}{d}\right) \quad (1)$$

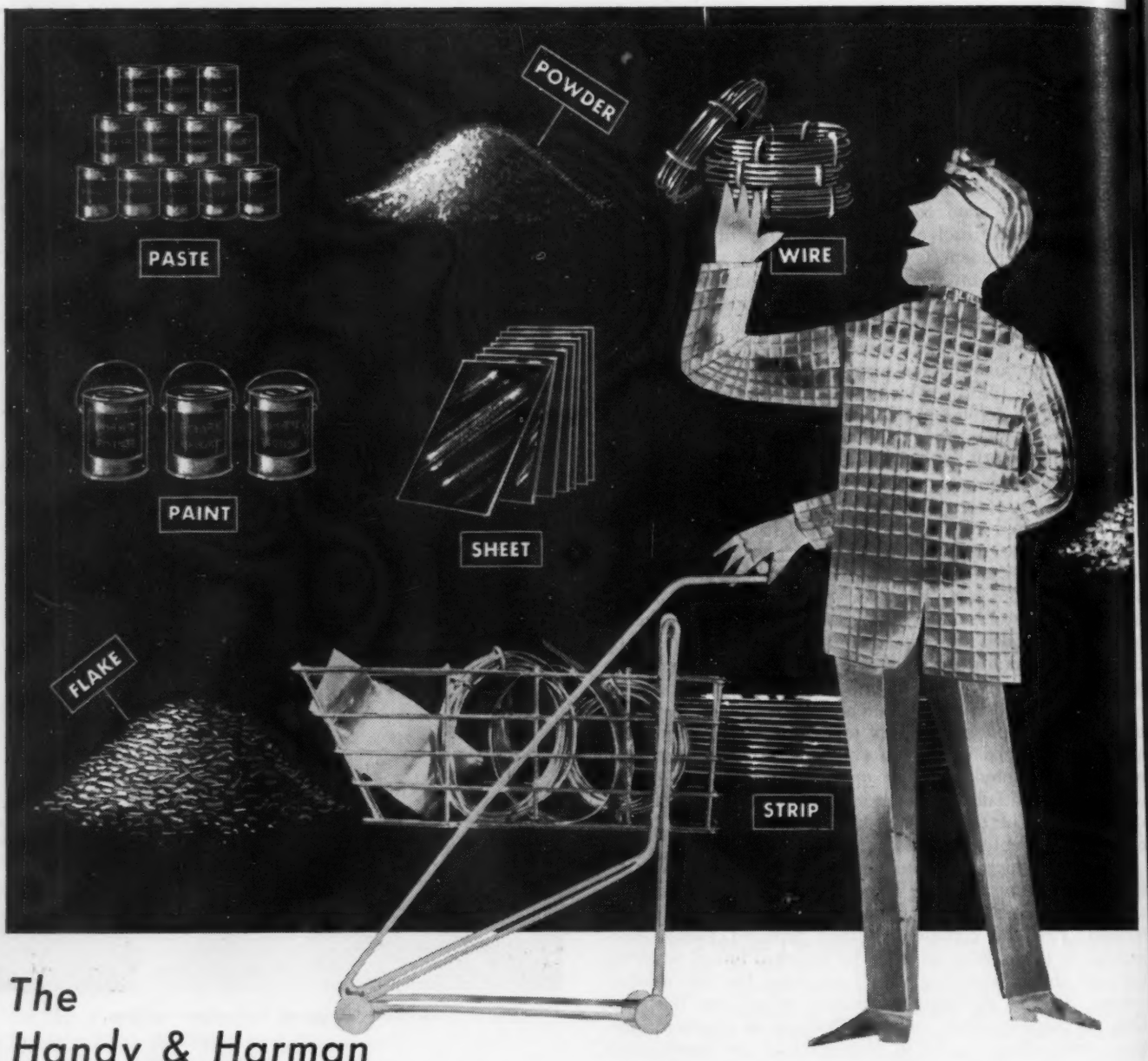
$$V_{Hmax} = \frac{3\pi}{8} B \left[P_{max}\left(\frac{w}{ld}\right)\left(\frac{\mu}{qn}\right)\right]^{1/2} \quad (2)$$

$$Z_o = \frac{\rho w}{ld} \quad (3)$$

$$\frac{\delta V_H}{\delta_T} = -KT^3\left[3 + \left(\frac{qV_g}{kT^{3/2}}\right)\right] e^{-(q/2kT)\,V_g} \quad (4)$$

$$\text{where } K = \frac{0.59\ BI}{d}\left(\frac{2\ \pi\ mk}{h^2\ N_d}\right)^3$$

and B = magnetic field strength
h = Planck's constant
I = control current
k = Boltzmann's constant
l, w, d = crystal dimensions (see Figure 1)
m = electron mass
n = electron density
N_d = density of donor atoms



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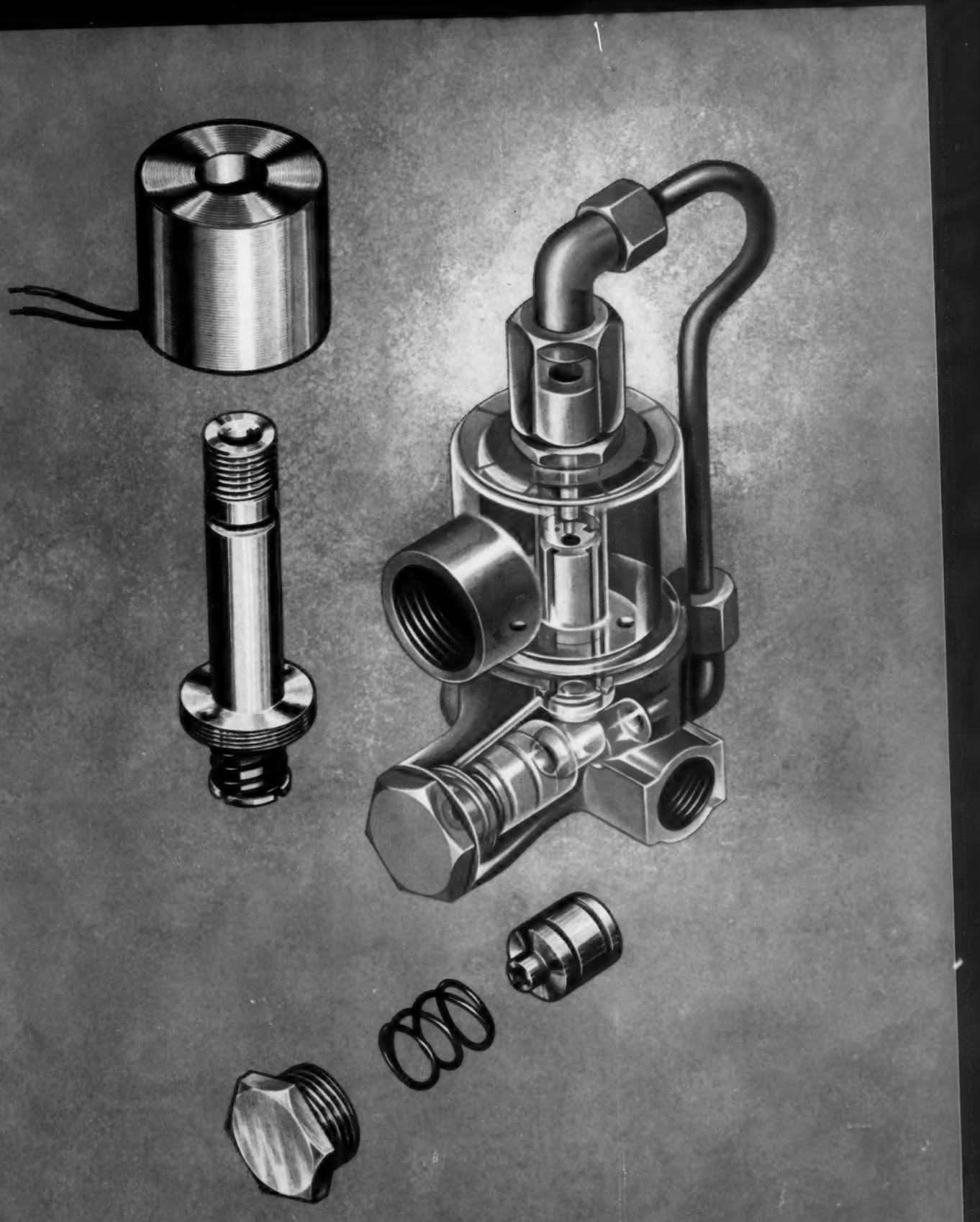

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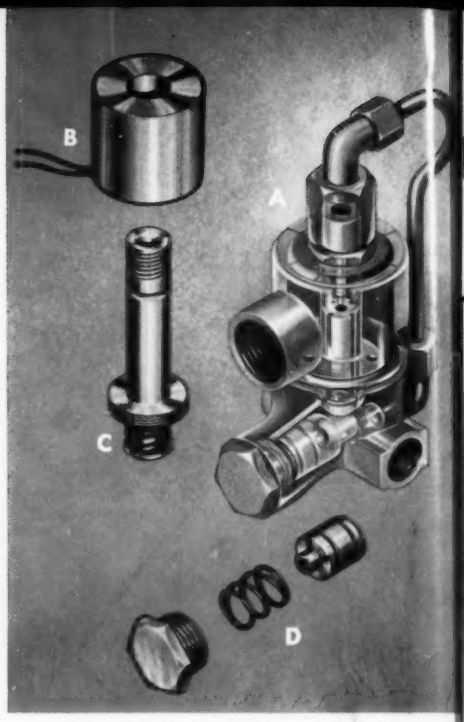
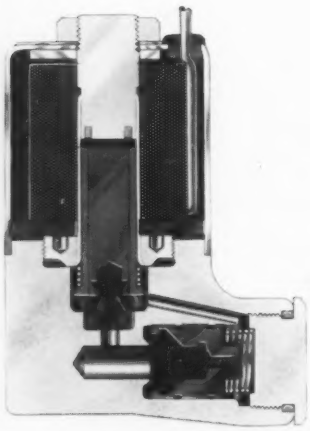


A—Transparent view of normally open 2-way R type valve with piped pilot exhaust return
B—Coil C—Sleeve, plunger and spring assembly
D—Piston assembly with soft synthetic insert



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Skinner R series two-way valves have forged naval brass bodies to provide a dense metal structure and use a foolproof stainless steel piston with soft synthetic insert to open and seal the main orifice. Types are available normally open or normally closed, in standard and explosion-proof construction.

To make installation easy for every application, a wide choice of electrical housing options is available. These include JIC, AN connector, automotive terminals, etc. All housings can be rotated 360°. Manual override is also offered to permit manual opening of normally closed valves, or closing of normally open valves, in emergency.

Skinner R series valves may be used with all common voltages and frequencies and there are several coil types such as: varnished, molded waterproof, tropicalized and high temperature for specific applications.

The R series, illustrated here, is just one in a complete range of 2-, 3- and 4-way Skinner solenoid valves.

TWO-WAY R SERIES SPECIFICATIONS

Types	R2 XR2	R2H XR2H	R2H6	RP1 XRP1
Position	Normally closed	Normally closed	Normally closed	Normally open
Pipe Size (NPTF Dry Seal)	¼"	¼"	¼"	¼"
Orifice Size	¼"	¼"	¼"	¼"
Cv Factor	.758	.758	.758	.758
Operating Pressure Differential (PSI) Minimum	5	5	5	5
Maximum AC Service	200	1250	—	150
Maximum DC Service	200	500	1000	150
Leakage	Bubbletight	Bubbletight	Bubbletight	Bubbletight
Temperature Range (Ambient and Media)	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F	Minus 40°F to plus 180°F

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TABLE I Characteristics of Hall-Effect Materials

Material	Energy Gap, V_g (electron-volt)	Mobility, (M^2/volt-sec)	Resistivity, (ohm-cm)	Output, V_H (mv)
Indium Antimonide (In Sb)	0.18	6.50	0.006	144
Indium Arsenide (In As)	0.33	2.40	0.009	64
Indium Phosphide (In P)	1.28	0.40	0.163	453
Germanium (Ge)	0.72	0.36	10.000	316
Silicon (Si)	1.10	0.12	100.000	336
Gallium Arsenide (Ga As)	1.35	0.32	0.005	6

P = power dissipation
q = electron charge
T = temperature
V_g = energy gap
V_H = Hall output
μ = mobility
ρ = resistivity

Equation (2) above suggests the following possible figure of merit ξ for Hall generators:

$$\xi = (\mu/qn)^{1/2} = \mu\ (\rho)^{1/2}$$

Making use of this figure of merit, and assuming certain values for resistivity typical of the materials currently available, Table I presents some typical characteristics of Hall-effect materials. The values are based on semiconductor crystals of dimensions 0.125″, 0.250″, and 0.005″ in width, length, and thickness, respectively. A magnetic field of 1200 gauss and a power dissipation of 0.1 watt were assumed. It should be recognized that variations in the tabulated properties are readily attainable. For example, it is possible to specify different degrees of doping, and thus obtain different values of resistivity.

Values listed for energy gap, as well as degree of doping, may be used as figures of merit for the temperature dependence of the material. This relationship can be seen from expression (4) above, which indicates that the higher the energy gap and the degree of doping, the smaller the voltage variation with temperature. However, this fact introduces a design conflict of interest. Increased output from a given basic semiconductor material can be obtained by specifying lower degrees of doping, which results in increased values of resistivity and mobility. The output is thus increased (see Figure of Merit given above), but at the same time, temperature stability is decreased by the reduced impurity concentration. Unless temperature control can be supplied, a compromise value for degree of doping must be selected.

Table I suggests the advisibility of considering germanium and silicon as generator materials for the solid state resolver. This approach is strengthened by a consideration of magnetoresistance effects which are known to vary di-

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rectly as the square power of the mobility. Since the mobility figures for germanium and silicon are much lower than those of the materials in available commercial generators, the magnetoresistance effect is greatly reduced and, as a result, the control current remains constant as the unit is rotated in the magnetic field.

Output impedances observed in generators made from germanium or silicon are substantially higher than those in commercial units. But this condition does not present too great a problem when the output feeds into a high input impedance buffer stage.

As mentioned above, this analysis is primarily directed at voltage measuring applications, such as the Master for the Automatic Resolver Test Console. In developing a line of solid state synchros, however, analysis from the standpoint of power delivery must be made. Such analysis and laboratory investigation will be reported in the near future.

After selection of the semiconductor crystal material came the problem of determining the best means of attaching the electrode leads to the material. A number of methods are available for obtaining good mechanical bonds. Among the more prominent are:

Plating in a Liquid Bath – the semiconductor slab is placed in a liquid plating bath at controlled temperature, and a layer of metal is coated on the material either by chemical reaction or electroplating.

Plating in a Vapor Bath (Vapor Decomposition) – the semiconductor material is placed in an atmosphere of carbon dioxide and nickel carbonyl; the temperature and the proportions of the mixture are carefully controlled. Very pure metallic nickel is then deposited on the semiconductor slab.

Vacuum Sputtering – high voltage is impressed between the semiconductor material and gold in a highly evacuated chamber. The metallic gold cathode disintegrates and a gold deposit forms on the semiconductor material.

But these techniques, while yielding good mechanical bonds, are not satisfactory for germanium and silicon. With these materials, the bonds formed are not ohmic, resulting in distortion of the Hall voltage output at small values of input control current. This distortion does not permit a clean sine wave output for normal Hall-effect generator control currents. To secure ohmic contacts, one of the following techniques may be employed:

A pellet of gold-antimony alloy is held in physical contact with the silicon slab in a jig of special purity carbon. The combination is heated in an atmosphere of inert gas (for example, Argon) at 400 to 500°C. Lead and tin alloys may be used in place of gold.

The semiconductor slab is plated with a gold-antimony alloy. Then the material is heated in an atmosphere of inert gas.

The vacuum sputtering technique described above can be followed by heating in an atmosphere of inert gas.

A gold-antimony wire is held in contact with the semiconductor material, and a bond is established by an arc-discharge through the junction point.

Each of the above alloying techniques results in the formation of an eutectic layer and satisfactory ohmic contact.

The problem of correct bonding is accompanied by a problem of correct lead placement to obtain minimum zero-field (misalignment) voltage. This can be achieved by employing precision fixtures and photographic etching techniques with the first three alloying processes described above, or by utilizing a special fixture with the arc-discharge method to obtain lead positioning at the desired electrical performance point.

Lead attachment is followed by encapsulation, which should not materially affect the performance of the assembled Hall-effect generator. Thick protective layers are desirable from the standpoint of mechanical strength for the device. However, it is necessary to compromise this feature because a thick assembly packaged into a slotted stator structure would require a large air gap and hence quite large permanent magnets.

Performance characteristics of the Hall-effect generator may also be controlled, up to a point, by proper selection of size and shape. If the shape is to be a rectangular slab, then equation (2) above suggests that increased output may be obtained by reducing the thickness and/or increasing the width-to-length ratio. The thickness can only be reduced to a certain point, beyond which linear Hall operation ceases, or the unit becomes too weak physically. Furthermore, the width-to-length ratio should not exceed 1:4 in order to prevent nonlinear operation resulting from a shorting effect between the control and output electrodes.

Of course, the effect of the dimensions on output impedance must not be overlooked. Optimum values for length, width, and thickness represent a compromise between Hall output, impedance, and other parameters under consideration.

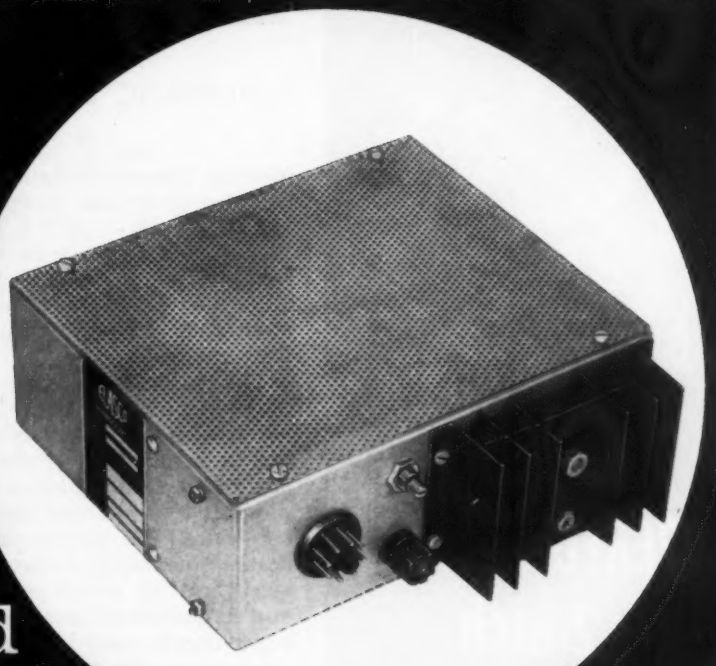
Application of Hall-effect generators to synchros and resolvers invites attention to shapes other than rectangular, in particular cylindrical. This shape lends itself to packaging into small assemblies, and suggests improved performance from certain standpoints because of symmetry.

A solid cylindrical generator is governed approximately by the equations given above. Therefore, the diameter will have to be held to a very small value to obtain workable Hall output voltages. The alternative is use of a thin walled cylinder, which suggests a generator in the form of a deposited metal film. Although some exploratory investigation has already been conducted in this area, much is left to be done in the way of mathematical analysis and experimentation before the true value of this approach can be accurately gauged.

Germanium and silicon generators assembled at the Kearfott Solid State Laboratory exhibit characteristics generally in line with the theoretical considerations described above. The zero-field voltages have been reduced to a large extent, and further bucked out to a few microvolts by means of cancellation circuitry. In addition, as a result of minimizing the magnetoresistive effect, no variation in control current was noted as the device was rotated in the magnetic field.

The output impedances are generally on the order of a few hundred ohms. Tests of functional accuracy reveal values comparable to precision wound counterparts. Further refinement is in process to advance the functional accuracy beyond this point.

A New Family of Transistorized Power Supplies



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Elasco power supplies are of modular construction and lend themselves to inclusion in proprietory products and test installations. Two SV-2A units may be mounted side by side on a 3½" x 19" rack panel, or mounted as a subassembly on either the 8½" x 8⅜" or the 8½" x 3" face.

Manufactured in accordance with the highest commercial standards and using high quality materials and components, Minisource® power supplies deliver value and reliability. Quality control is rigorous and each supply is performance checked for a minimum of 24 hours prior to shipment.

Military power supplies and modifications to standard models are made to customer specifications. *Send us your requirements.*

SV-2A MINISOURCE® SERIES SPECIFICATIONS

INPUT VOLTAGE: 105 to 125 volts

INPUT FREQUENCY: 60 to 400 cps

MODEL	VOLTS	CURRENT
SV6-2A	6	0-2A
SV12-2A	12	0-2A
SV18-2A	18	0-2A
SV24-2A	24	0-2A
SV28-2A	28	0-2A

Each variable to ±1 volt

LINE REGULATION: 5 millivolts

LOAD REGULATION: 30 millivolts max.

RIPPLE: 5 millivolts peak to peak

RESPONSE TIME: 50 microseconds or less . . . no load to full load

OPERATING TEMPERATURE: 0 to +50°C

DIMENSIONS: 8½" x 8⅜" x 3" high

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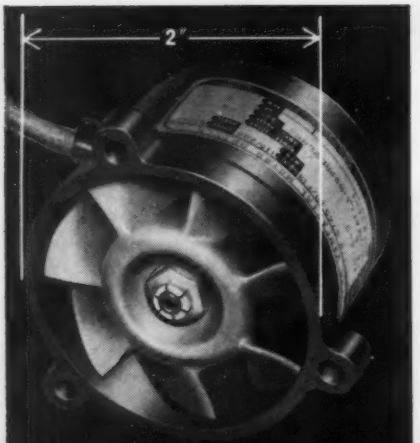

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Range of Specifications

- **Volume flow: 21.5 to 53.5 cfm**
- **Pressure rise: .6 to 3.44 H_2O**
- **Speed: 10,500 to 22,500 rpm**
- **Single, two or three phase power**
- **Power: 16 to 69 watts**
- **Standard or high slip motors**
- **Weight: .36 to .48 lb.**

A world leader in the design and manufacture of heat exchangers, fans and controls, AiResearch can assume complete cooling system responsibility. Your inquiries are invited.

*Minifan is an AiResearch trademark.

THE GARRETT CORPORATION

AiResearch Manufacturing Division

Los Angeles 45, California

CIRCLE NO. 16 ON INQUIRY CARD

AUTOMATIC SILVER-ZINC BATTERY

Internal Chemical Heating Device Permits Instaneous Full Power at Low Temperature

When reliable, reserve electrical power is needed in missiles and satellites, batteries now can supply plenty of it, almost instantaneously, despite subzero temperatures in space.

The Missile Battery Div. of the Electric Storage Battery Co., Raleigh, N.C. has developed a new silver-zinc battery that is reported to be the first automatically activated unit to incorporate successfully an internal chemical heating device. The battery needs no preheating from external electrical sources, yet it heats up to full-power temperature several critical minutes faster than conventionally-heated batteries.

Designed also to replace other reserve types of silver-zinc batteries of comparable capacity in existing applications, the chemically-heated unit delivers an average of 10 to 12½ watt-hours per pound, including the heating device. The battery, capable of quick power delivery in ambient temperatures as low as −65 F, is heated when electrical matches automatically ignite chemical powder to warm an electrolyte. The matches ignite the powder simultaneously with the explosion of an activating squib that releases gas under pressure, causing an alkaline electrolyte to flow within the battery.

Heating of the entire battery is almost instantaneous, because the ignited powder surrounds a copper-tube heat exchanger through which the potassium hydroxide electrolyte flows from a reservoir toward a pack of dry-charged zinc and silver-oxide battery elements. When the heated electrolyte reaches the elements, power output begins at once.

In some models, the electrical matches are controlled thermostatically so that heating takes place only if ambient temperatures are below normal operating range. In two versions of the battery, activation takes place within a maximum of six seconds over a temperature range of −65 to +165 F. Heating takes place at temperatures below 25 F. Both of these units, Types 88-19 and 88-78, can operate for 15 minutes, delivering a 20-amp current. Each weighs 12 pounds and has a volume of 186 cubic inches. They differ principally in such external features as mounting brackets and electrical terminals. A smaller, more compact model of the battery, the 88-89, is a 28-volt, 7.0 amp-hour unit that is designed to supply power for a load sequence varying from 50 milliamps to 17.5 amps. These and other models are available in a variety of shapes and physical and electrical sizes and are supplied in hermetically sealed canisters.

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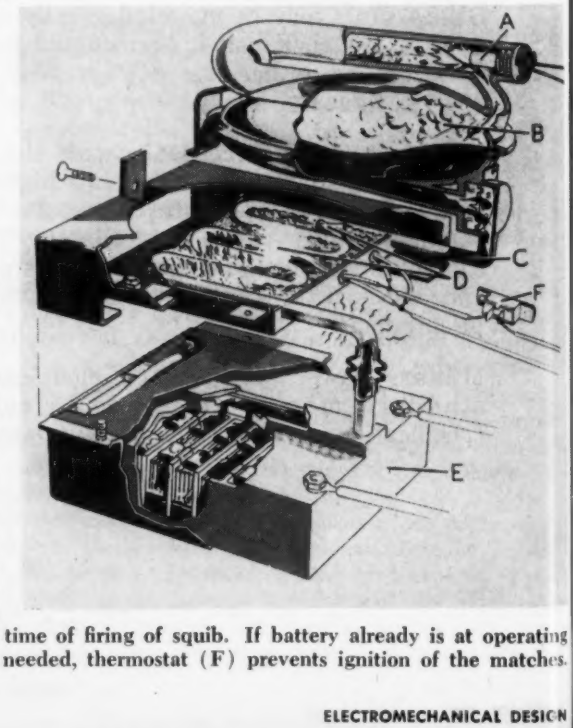

Sketch shows principle of automatically-activated silver-zinc battery that heats itself almost instantaneously to operating temperature. Squib (A) is exploded to release gas under pressure, thus expelling an electrolyte from reservoir (B) into tubing of heat exchanger (C). Simultaneously, electrical matches (D) ignite chemical powder surrounding heat exchanger tubing. Electrolyte then flows into pack (E) of dry-charged battery elements. Power output begins within seconds from the time of firing of squib. If battery already is at operating temperature when powder is needed, thermostat (F) prevents ignition of the matches.

PRODUCTION AIDS

If you want more information on the production aids discussed below write the appropriate number on the reader service card.

ELIMINATE SOLDERING **885**
with machine that fuses commutators on fractional hp motors; no more problems with creepage and the throwing of solder. Manual and automatic models, one of which is for use on very small armatures on small dc models, come with either synchronous tube or mechanical timers. Simple in operation, they require only unskilled workers. Joyal Products, Inc., Newark, N.J.

INDUSTRIAL AIRBRASIVE UNIT **886**
cuts and cleans semiconductor materials, adjusts micromodule elements, wire strips potentiometers, cleans leads and deburrs precision parts. Employing a controlled, high-speed stream of abrasive particles and propellant gases, the Airbrasive cuts or abrades hard brittle materials, such as germanium, silicon, mica, glass, fragile crystals and ceramics. Free tests on sample materials. S. S. White Industrial Div., New York, N. Y.

WIRE STRIP **887**
without nicking a wide range of wire sizes with only a flick of the thumb. Hand tool's adjustable stop automatically controls the length of the stroke up to ⅜ in. Pistol type construction enables its use in limited access areas, component parts, as well as open production lines. Kelsey-Hayes Co., Utica Drop Forge & Tool Div., Utica, N.Y.

DETECT CONTAMINATION **888**
with black light, a versatile inspection technique: detects hydraulic leaks, leaks in viscous-damped mechanisms, leaks of dc-55 and lubricating oils in instruments and meters, plastic particles in servos and gyros, excessive or insufficient varnish coatings on potentiometers, and fluorinated hydrocarbons on wiring harnesses. An ultra-violet radiation just beyond visible violet light, black light is harmless to skin and eyes. Ultra-Violet Products, Inc., San Gabriel, Calif.

CLEAN SMALL PARTS **851**
and sub-assemblies ultrasonically with a transistorized system, powered by a 75-watt generator driving a transducerized tank at a nominal frequency of 25 kc. The company suggests using the unit for experiments with ultrasonic cleaning before purchasing larger, more expensive equipment. Branson Instruments, Inc., Stamford, Conn.

INSULATE SORE THUMB CONNECTIONS **852**
on electrical motors with a new rubbery silicone adhesive. The fast procedure consists of filling the molded connector caps with the room-temperature-vulcanizing silicone rubber contained in a squeeze tube. Filled caps are installed over each coil connection. Within 24 hours it cures to a rubbery solid and becomes an integral part of sealed silicone rubber insulation systems. Dow Corning Corp., Midland, Mich.

INFRA-RED RELAY **890**
for detecting temperature changes can be employed at a distance from hot forming processes to actuate water sprays, take-up reels, pouring devices, furnace doors, conveyors, shears, counters, and other auxiliary equipment. The optical system and detector element provide a discriminate field of vision approx 12 sq in at a distance of 20 ft from the relay, 6 sq in at 10 ft, etc. Set for maximum sensitivity, the relay is energized by an object 10 ft distant as small as 1 sq in, at a temperature of 1100 F and moving at a speed of about 6 ips. As long as the hot object remains in the optical field of vision, the relay will remain energized. It requires no water cooling. Daystrom, Inc., Newark, N.J.

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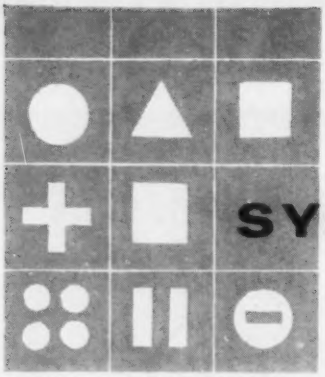


SYSTEMS DESIGN

SECOND ORDER EFFECTS IN AC TO DC POWER SUPPLIES

P. A. Alessi, *President, Anders Electronics, Inc., Needham Heights, Mass.*

In preparation of specifications for the design of a power supply, knowledge of second-order effects can mean the difference between success and failure. Too often the power supply or power system is given little thought and the subsequent total system performance suffers. This article discusses some of the practical problems and systems considerations in design and application of power supplies. Highlighting second-order effects, it emphasizes some characteristics usually not considered in power supply specification.

INDUCTORS AS CHOKE INPUTS OR SATURABLE REACTORS

Inductors are often used as choke input filters in unregulated power supplies or as saturable reactors in regulated supplies. In most applications they don't cause trouble. However, harmonic radiation of inductors, especially near the saturation region, can cause high gain circuits to malfunction. Use of inductors should therefore be avoided wherever possible. Where they are necessary or highly desirable, the necessary precautions dictated by the associated load or circuitry must be taken. A double mu metal shield is very effective under adverse conditions, reducing radiated noise to a minimum.

A note of caution in the use of saturable type controls for power supplies: they are limited to a very narrow line frequency range, normally 1 or 2 cps, and therefore may not be useable where line frequency fluctuates 5 or more cps. However, saturable reactor controlled power supplies have become popular in the extremely high current range for 60 cycle operation in conjunction with low gain circuits.

EFFECTS OF CAPACITORS AT INPUTS AND OUTPUTS

Capacitor input filters in regulated power supplies have become more popular for the reasons indicated above. But, as with inductors, consideration must be given to their proper application. For example, if the transformer voltage form factor or harmonic distortion is poor, the rectified capacitor voltage may drop below the required regulated voltage.

Capacitor input filter power supplies require increased ratings of the power transformer and rectifiers because of the surge current drawn at the crest or peak of the voltage. The I^2R losses are much higher with a capacitor input filter than with a choke input filter.

In many cases where silicon or germanium rectifiers are used, a peak current limiting resistor should be inserted, particularly where large electrolitic capacitors are used. Also, the ripple current of the electrolitic capacitors should be limited by paralleling more units, in accordance with recommendations made by the manufacturers. The capacitor voltage rating should be at least 50 percent greater than what is normally supplied by the rectifiers under load conditions. This requirement is due to the poor regulation of a capacitor input power supply and under no load conditions may result in as much as 1.4 times the voltage at full load.

A capacitor across the output will improve operation of the regulated power supply by reducing impedance. Also, in many cases where oscillation occurs, the proper selection of a capacitor and small series resistor will shift the phase sufficiently to eliminate oscillation. A capacitor across the output is not the complete answer in the case where the load frequency may be high and the leads between the power supply output and the load have sufficient inductance to cause large voltage spikes at the load.

EFFECT OF RECTIFIERS

Rectifiers develop switching transients, normally called rectifier commutation. High current commutation can cause problems if coupled into the amplifier circuit of a regulated power supply. Therefore, caution should be taken in the placement of the rectifier leads with respect to high gain circuits.

Many types of rectifiers are now on the market: vacuum tube, selinium, germanium, silicon, etc. Solid state rectifiers have a high efficiency factor due to the low forward voltage drop. However, in the case of silicon, destruction of the rectifier may occur during power "turn off". This phenomenon is more pronounced with silicon rectifiers with very high back resistance and is caused by the high reverse voltage developed by the transformer or choke due to $L\,di/dt$ when power is turned off. A damping capacitor across the transformer winding will solve this problem.

EFFECT OF TERMINATING LEADS

Termination of power supply leads can become a major problem if the overall power distribution is not considered in advance. In a simple case where a single regulated power supply is required for a particular load, lead length can be compensated by the use of sensing leads terminated at the load. Both positive and negative sensing leads are necessary for complete effectiveness. Even in this simple case, additional compensation is required for high frequency loads (20 KC and higher). For such loads, it is advisable to apply capacitors directly across the load. The type and size is determined by the load; for load frequencies greater than 1MC, paper or tantalum capacitors may be required.

EFFECTS OF DC POWER DISTRIBUTION

In the design of complex electronic equipment such as a computer system, power distribution is a very important factor and should be considered as part of the basic system design. Many problems and side effects are encountered in such systems, especially where pulse circuits with low impedance de-

vices, such as transistors, are normally used.

Ground loops and load current accumulation in dc buss distribution may, and usually, cause interaction between circuits. Basically, three rules can be followed for good practice in minimizing dc power distribution problems, particularly in a large system.

- A ground or common should have the characteristics of a point source. Copper buss size should be sufficiently large to reduce accumulative load effects. In most cases, a practical size allowance would be between 1,000 and 2,000 circular mills per ampere per linear foot. Some critical applications require larger allowances.
- DC voltage distributions from various loads to the power supply should have as many branches as are practical. Increasing the number of branches reduces interacting effects.
- To further reduce interaction between circuits on a single buss, decoupling RC networks are usually required for each major circuit. These networks will also cancel the inductance effect of leads in high frequency circuits.

EFFECTS OF REGULATION AND RIPPLE

Too often specifications for regulation and ripple in a power supply are set too tight, resulting in an expensive unit. A normal range that meets most requirements economically is as follows:

Choke Input Power Supplies	
Load Regulation	8 to 10%
Line Regulation	none
Ripple (VRMS)	0.5 to 2%
Regulated Power Supplies	
Load Regulation	0.1 to 1%
Line Regulation	0.1 to 1%
Ripple	1 to 10 MV

The dc resistance of a power supply defines its load regulation

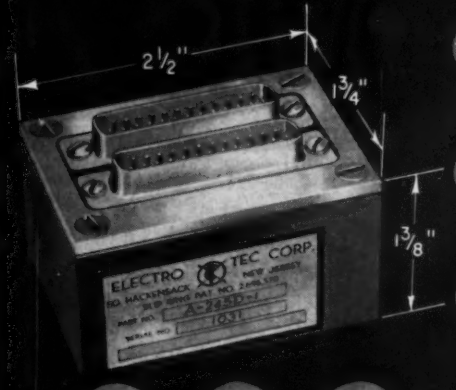
$$\Delta e/i = R_o$$

where e = output voltage differential, i = load current, R_o = internal dc resistance;

whereas the ac impedance is affected by the capacitor across the output. Negative resistance (over compensation) can be achieved by inserting a resistor between the reference and sensing network junction point, normally connected to one side of the output leads. This method is normally used to compensate for load and thereby reduces the task and complexity of the control amplifier. It is sometimes called current compensation.

High gain amplifier circuits and their leads should be isolated from power

A SIGNAL ACHIEVEMENT IN TELEMETRY... ELECTRO-TEC'S NEW 450-CIRCUIT COMMUTATING SWITCH



Electro-Tec's new compact 8-oz. motor driven telemetering switch enables circuit combinations up to a maximum of 5 poles, 90 channels per pole . . . truly the answer to precision performance with optimum size and weight.

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SIZE 11 DC TACHOMETERS

These Kearfott DC tachometers are unusually durable and specifically designed to provide reliable service over a long life. R9608-001 is an uncompensated unit ideally suited to function as a stabilizing element in a standard DC servomechanism. The R9608-002 model offers the precision required in computing applications and is temperature compensated to maintain its high accuracy over the temperature range of −15°C to +71°C, with variations of no more than .1% of values specified at 25°C.

		R9608-001	R9608-002
TYPICAL ELECTRICAL DATA	Output (volts/1000 rpm)	7 (typical) .5-30 available	2
	Rated Speed (rpm)	3600	5000
	Linearity (% to 3600 rpm)	.07	.1
	Winding Resistance (ohms)	125	
	Output Impedance (ohms)	—	36
	Ripple Voltage	2% above 100 rpm	2.5% at 3600 rpm
TYPICAL MECHANICAL DATA	Friction Torque (in. oz.)	0.25	0.25
	Rotor Moment of Inertia (gm-cm²)	7	8
	Weight (oz.)	5.5	5

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GENERAL PRECISION, INC.

Little Falls, New Jersey

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leads containing high ripple currents which may cause spikes or oscillation.

EFFECTS ON PASSING ELEMENTS (Series Regulators)

Passing elements, either transistors or vacuum tubes, should be selected to operate over the complete voltage range including effects of line voltage swing and wide load conditions. The worst condition for maximum voltage across the passing element is at high line and minimum or zero load. In the case of transistors, the critical parameter may be the output rectified voltage at no load if during a short circuit the passing transistor becomes biased off.

The passing elements should also be capable of dissipating full power at high line and full load at maximum ambient temperature. This precaution will result in extended life.

Consideration must be given to balancing the load current between parallel passing elements to prevent a runaway effect resulting from rapid deterioration of the heavily loaded elements, one after the other. One of the best forms of balancing is to have sufficient degeneration in the cathodes or emitters of each passing element to balance the currents to within 10 percent.

EFFECTS OF COMPONENTS

Reliability of a power supply is improved by reducing the number of components, within the limits of proper design. It is therefore advisable to eliminate any extra features or auxiliary circuitry not absolutely necessary. Derating of components must be done for the worst conditions, such as high or low line, full load and minimum load. In many cases, maximum dissipation of a resistor may occur at low line or minimum load, or both, in which case deterioration may result rapidly.

GENERAL CONSIDERATIONS

Good regulation in a power supply is often necessary, but more often it is not an important factor. For example, in one system, a high speed output converter for a digital computer containing over 13,000 tubes and 5,000 transistors, it was more important to overcome line voltage transients than to have a high degree of regulation, since the basic circuit modules of the system were designed with a wide dc voltage range of ±15 percent. With use of unregulated dc power supplies, the overall efficiency

of the power system was about 80 percent.

An electronic fly-wheel effect (high capacitor inertia) was used to attenuate line voltage transients as well as load transients. The resulting power system with proper bussing became very effective with a minimum of problems. In addition, a high degree of reliability was achieved because of the limited number of heavy duty components.

TRANSISTORIZED POWER SUPPLIES

Some factors that should be considered in design or specification of a power supply with transistor circuits are:

- To prevent transistor circuit burnout from turn "ON" and turn "OFF" overvoltage transients, the dc output should stay within 10 percent of the output setting from zero to full load.
- Short circuit protection of the output should be designed to saturate the passing transistors and blow a fuse, or to bias them off to reduce the current to near zero.
- Overvoltage protection can be achieved by a shunt diode or a shunt transistor. This feature may be necessary wherever transistors in the load are operating near the avalanche voltage rating.
- Current limiting may be required for certain transistorized circuits. Caution should be taken to insure the passing transistors are capable of full dissipation with the output shorted.

For a reprint of this article and more specific information,

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Checkout System

Electronic laboratory capable of field-testing complex weapon systems occupies a cabinet the size of a bedroom chest-of-drawers and weighs less than 1,000 lbs. The Central Programmer and Evaluator also checks itself to verify the accuracy of its results and guard against its own malmunctions. The highly versatile equipment can test missiles, aircraft electrical equipment, fire control systems, flight simulators, communications equipment, factory controls, business machines and even television sets in a matter of minutes. Consisting of a series of removable units, the evaluator operates automatically from taped messages. Goodyear Aircraft Corp., Akron, Ohio.

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INERTIAL QUALITY

SINGLE AND 2 AXIS ACCELEROMETERS

Highly precise and accurate, Kearfott's accelerometers are pendulous devices which sense airframe acceleration forces acting on them.

A pendulum utilizing a unique Hooke's joint suspension displaces as a function of acceleration. An AC pickoff signal is rectified and applied to voice coils restoring the pendulum to null. The DC required for restoration is proportional to acceleration. Typical characteristics for these units include range of ±25 g's, scale factor of 5.0 ma/g, linearity of ±0.005% and threshold of 2 x 10^{-7} g's.

CHARACTERISTICS:

TYPE NO.	SINGLE AXIS F2401	SINGLE AXIS 429037	TWO AXIS 326778-1
Range of Measurement	±20g	±25g	See above
Scale Factor (output)	5.0000 ma/g	5.0000 ma/g	
Operating Temperature	155°F ±5°F*	50°F and +160°F	
Threshold	5 x 10^{-7}g	Less than 2 x 10^{-7}g	
Zero Stability	±0.05 milliradian	±.00005g day to day	
Vibration	Up to ±10g peak from 20 to 2000 cps	Up to ±5g peak from 20 to 2000 cps	
Storage Temp.	−65°F to +200°F	−60°F to +170°F	
Scale Factor Variation	±.01% randomness	±0.01% randomness	
Excitation	6 volts, 3860 cps**	6 volts, 4000 cps**	3.4 volts, 4000 cps***
Natural Freq.	180 cps	210 cps	160 cps
Freq. Resp.	Flat to 250 cps	Flat to 160 cps	Flat to 100 cps
Shock	60 g's	30 g's	30 g's
Weight	4 oz.	7 oz.	2 lbs.

*Available for 180°F.
**Carrier frequency to 100 Kc may be used.
***When tested with Kearfott A3501-01 amplifier.

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Little Falls, New Jersey

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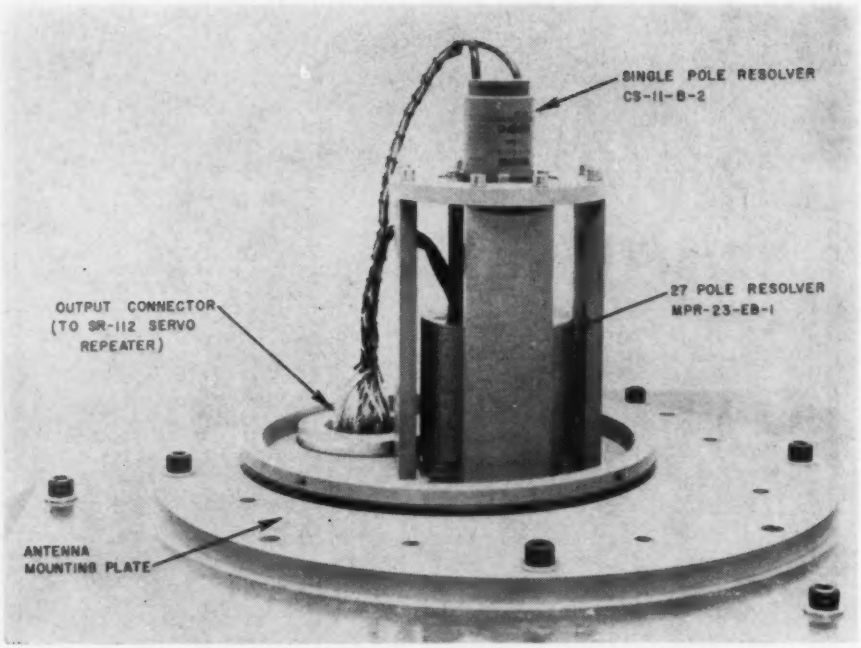


Closeup of the ST-103 Servo Transmitter, part of the servo repeater used in the antenna angle measuring system for tracking Echo I Satellite.

SATELLITE TRACKING

Digital Equipment Provides Accurate Tracking Data

A highly accurate antenna angle measuring system installed at the NASA-JPL facility in California's Mojave Desert automatically records and displays the space coordinates of the communications satellite Echo I as the 100-foot sphere speeds around the earth at 16,000 miles per hour in a circular orbit 1,000 miles up. The system also provides data for direct input into a high-speed digital computer.

An RMS accuracy of better than 18 seconds is achieved by using a multipole computing resolver on each axis of the tracking antenna. A servo follow-up unit at the base of the antenna, utilizing a single-pole computing resolver, multiplies the antenna rotation by 90 to provide decimal data for recording and display. Multiplication by 128 is also performed to provide straight binary input to the digital computer.

Heart of the data system built by Datex Corporation consists of a pair of precision Datex encoders for each axis of the tracking antenna. One is a decimal encoder that digitizes the antenna's angular position to one part in 180,000, or every 0.002 degrees. The other is a binary encoder that digitizes the antenna position to one part in 262,144, or every 0.0014 degrees.

Output of each encoder is translated from its special Datex code to ordinary decimal and binary codes in all-transistorized translators capable of operating in either of two distinct modes. In the first mode they can continuously follow the antenna position. This mode is useful in searching for a satellite whose position is not accurately known.

In the second mode the translators sample and store the antenna position in an internal memory for transfer to a computer or recording device. This mode is for use where the translator is under command of an external device.

Because the value of the recorded data depends on the exact time it is sampled, an electronic digital clock is included in the system. The clock operates by counting pulses from a high-stability 100-KC oscillator. Thus the satellites position is recorded on paper tape along with the exact time that the satellite's position was sampled. The paper tape record of the satellite's transit is then available for future study.

Write No. 158 in Box on Inquiry Card

Sampling System

To satisfy the new requirements for an economical solid state sampling system, Vector Mfg. Co., Inc., Southampton, Pa., has designed a transistorized commutator for simultaneous sampling of millivolt and volt signals of high and low levels. Embodying the modular concept, the commutator has wide range of sampling speeds for PCM, PDM, and PAM commutation systems. Due to the absence of back current, no specialization of transducer loading effects is necessary. Major component of the system is a timer which contains the necessary circuitry for driving the sampling gates at the desired rate and proper sequence. Standard timers, at the rate of 900 pps, are capable of driving 28, 43 or 88 channel input samplers. Although 900 pps is the standard sampling rate, the timer in combination with the input sampling gates and the differential amplifier can operate at speeds in excess of 25,000 pps; high level gates consisting of single ended input switches transfer the information from the transducer to a common output load when the information varies between 0 and 5 volts. Low level gates are double ended input switches that accept the low millivolt signal outputs (0 to 10 millivolts) from bridge and thermocouple type transducers. A differential amplifier converts the dual output of the low level gates into a single ended pulse train in the 0-5 volt range. Vector Mfg. Co., Inc., Southampton, Pa.

Write No. 619 in Box on Inquiry Card

WORTH FILING

Semiconductor Devices

Brochure covers 800 semiconductors, including ratings, characteristics and descriptions on silicon glass diodes, silicon small power, medium and high power rectifier cells, high voltage cartridge rectifiers, zener diodes and reference elements, silicon controlled rectifiers, silicon and selenium rectifier stacks, silicon solar cells and selenium contact protectors. 24-page catalog also comprehensively lists JEDEC rectifier types, with cross reference to device classification, rating and page number. For your copy: Write on your company letterhead to:

International Rectifier Corporation,
El Segundo, California.

WORTH FILING

Cooling Electronic Equipment

What the engineer should consider when designing cooling systems for electronic equipment is the subject of a 32 page treatise. Factors such as air distribution, noise and humidity are described as well as techniques and equipment for controlling them. A nomograph insert establishes approximate air conditioning requirements for critical areas. One chapter treats peculiarities in electronic air conditioning systems.

Source: Ellis & Watts Products, Inc.
Cincinnati, Ohio
For your copy: Write No. 807 on Inquiry Card

Lock-Nuts

Details of design and locking principle, advantages, typical applications, load ratings, materials and finishes of spring tempered steel lock nuts are included in a 24 page catalog. Regular hex, integral washer, acorn, wing and adjusting nut types are covered.

Source: The Palnut Co.
Mountainside, N. J.
For Your Copy: Write No. 841 on Inquiry Card

Blowers and Fans

Condensed 8-page catalog contains extensive technical data relating to selection and understanding of cooling devices. Company spokesmen said that to their knowledge this is the first time this information has been made available in one package to persons concerned with specifying and purchasing air-movers for critical applications.

Source: IMC Magnetics Corp.
Westbury, L. I., New York
For your copy: Write No. 802 on Inquiry Card

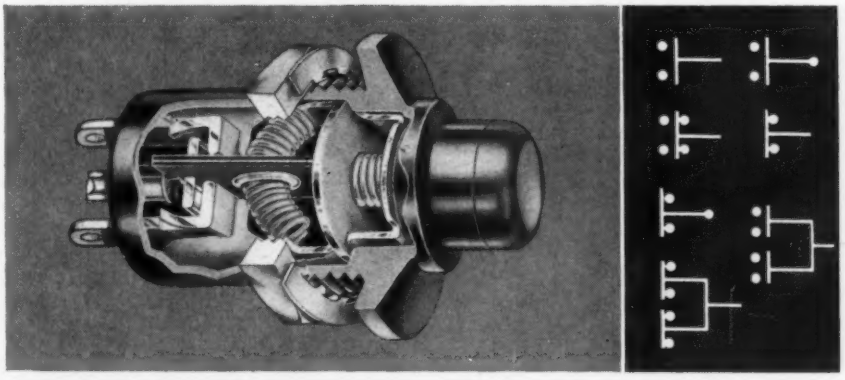
Band Clamps and Couplings

Full product information on industrial band clamps, hose clamps, couplings, flanges and v-band joints for all types of applications is contained in a new 44-page catalog. Comprehensive dimensional and operating data provide design engineers with important facts and advantages needed in original product design work. V-band couplings, for example, can be designed into original equipment to eliminate costly swing nuts and bolts.

Source: Aeroquip Corporation
Los Angeles, Calif.
For your copy: Write No. 801 on Inquiry Card

SWITCHES

FOR AIRBORNE & MISSILE GROUND SUPPORT EQUIPMENT



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LONG SERVICE LIFE • MOISTURE-PROOF

ELECTRICAL DOT ASSEMBLIES

A broad line of sinusoidal toggle spring switches designed for compactness, light weight and high reliability in airborne and ground support missile control systems. Extremely fast, audible, double break action reduces arcing and contact wear to negligible minimum. Positive snap action mechanism cannot be teased on or off contact. All contacts made of heavy coin silver for long life and low contact resistance. Available with color coded buttons. These switches exceed military requirements for vibration, shock, humidity and corrosion resistance.

Western Distributor: Western-Electromotive, Inc., Los Angeles.

The UCINITE COMPANY
Division of United-Carr Fastener Corporation, Newtonville 60, Mass.

CIRCLE NO. 21 ON INQUIRY CARD

Vigorous New Program in Industrial & Commercial Computers

It is estimated that the next 2 years will see a 33% increase in non-military use of computer equipment. General Electric's Computer Department is meeting these projected needs with a vigorous program of design, applications and sales.

We are now conducting a successful operation, and anticipate the capture of an even larger share of the market. Since we have set out to establish leadership and accelerate growth, the men we add to our staff must be of the highest competence.

A substantial range of opportunities is now available in Phoenix, Arizona and Palo Alto, California.

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EEs and MEs – plus experience in computer or electronic systems design. Advanced systems engineering on large and small commercial systems as well as industrial and process control systems:

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. . . at the Computer Laboratory on projects centering on:

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COMPUTER DEPARTMENT

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WITH THE NEW SELF TUNING AUTOSONIC BY POWERTRON

Powertron Autosonics are the only cleaners that continuously tune themselves electronically to give you peak cleaning efficiency. Regardless of load changes, liquid level, liquid temperature, or operator inattention, you get top cleaning performance hour after hour with no controls other than a single switch

The Powertron self tuning feature is available in a complete line of Autosonic tank units, consoles, cabinet models, immersible transducers, and vapor degreasers that . . .

ELIMINATE OPERATOR TRAINING AND MONITORING
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REDUCE REJECTS
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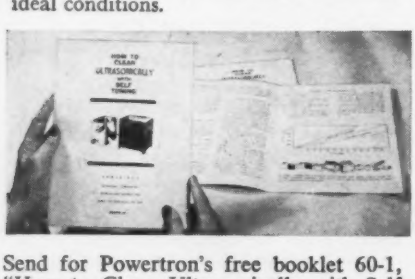
*Case histories on file show up to 900% faster cleaning consistently and savings as high as $3,000 a month in labor costs under ideal conditions.



Send for Powertron's free booklet 60-1, "How to Clean Ultrasonically with Self Tuning."

POWERTRON ULTRASONICS CORPORATION
DEPT. E-MD- • 1 PATTERSON PL., ROOSEVELT FIELD
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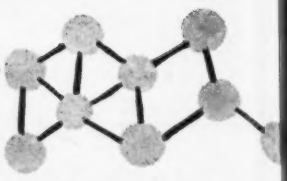
CIRCLE NO. 23 ON INQUIRY CARD

by **David Bandel** *Staff Columnist*
Associate Technical Director,
TRACERLAB, INC.



MATERIALS

High temperature materials research has proceeded along two paths: refinement of old standbys to squeeze out more performance and synthesis of new materials with inherent thermal stability. Most attention has been focussed on structural applications of these materials, which were certainly the most pressing primary problems. But now that these problems are on the way to solution, electronic and electromechanical engineers are going to inherit the problems of engineering the devices that go into these structures. This is clearly the next round in the process of screwing down on specifications for future development and procurement. The limits on heat transfer have been reached by now and since we can't beat them, we will have to join them, by developing components that can stand the heat.

Capacitors represent a weak link in the component field for high temperatures. While dielectric materials are available that have the requisite thermal stability, the resistivity generally decreases rapidly with temperature, approximately 1 order of magnitude per 100 C. The answer to this problem is not an obvious one; we need to know more about the causes of the decrease in resistivity as temperatures increase. Solid state chemistry and physics may produce some answers to this problem.

Titanium diboride, a new high temperature material, has been announced by National Carbon Company. A special process for the reduction of titanium and boron oxides produces high purity powders that can be fabricated into complex shapes, some weighing up to 260 pounds. Titanium diboride retains its flexural strength of 35,000 lbs/in ^{2} up to 2000 C. It has half the density of steel and a hardness in the range of boron carbide. This suggests its application in ball and roller bearings for high temperature service and as a die material for wire drawing. One interesting property of titanium diboride is its high conductivity, 20-30 micro ohm-cm at 20 C. and 80-100 micro ohm-cm at 1000 C. The coefficient of thermal expansion is in the range of ceramic materials, 8.1 x 10^{-6} cm/cm from room temperature to 1300 C.

Alumina, an old reliable of high temperature materials, has been worked over by Coors Porcelain Co. They have used a new type of high purity alumina refractory body to produce low loss, high strength, vacuum tight bodies. The loss tangent is reported to be 5.9 x 10^{-5} at 9200 Mc. The high dielectric constant of 9.27 has always made this material attractive as a high temperature dielectric for capacitors. It still appears to be the best for the range of 500 C and higher, particularly if the ionic impurities can be kept low to obtain the necessary high resistivity.

Lubrication at high temperatures is another problem generated by the push to extend the thermal barrier. A new high temperature lubricant, Phosphatherm RN, has been announced by Alpha-Molycote Corp. This lubricant is entirely inorganic in nature, a eutectoid mixture of phosphates that softens at high temperatures and forms an adherent coating with good lubricity on metal substrates, especially alloy steels. The lubricating film resists temperatures up to 2200 F, it is reported. Application of the coating is extremely simple. Water is added to the powder to form a viscous paste or a solution which is applied to the surfaces and heated. The powder can also be applied to the surface directly if the temperature is above 400 F.

An epoxy glass insulating material that retains its high dielectric strength and flexibility under continuous Class F temperatures is available from the Irvington Div., Minnesota Mining and Mfg. Co. The material is compatible with all Class F magnet wires, electrical resins and most other epoxy systems. The epoxy coated glass is flexible, conforms snugly on application and does not discolor after heat aging. Applications include: insulation in encapsulated transformers; phase, slot and coil insulation in Class F motors or in encapsulated motors; insulation in military units designed for short term operation at Class H temperatures and for all other Class F components.

Insulating Material

Expected to be a replacement for more costly laminated plastics in many applications, an insulating material, called Anilite, combines the electrical properties and mechanical strength of vulcanized fibre with the low moisture absorption of phenolic laminates and affords good dimensional stability and retention of insulating properties in a variety of atmospheric conditions. National Vulcanized Fibre Co., Wilmington, Del.

Write No. 590 in Box on Inquiry Card

Epoxy Resin Adhesives

Three epoxy resin adhesives cure at room temperature under contact pressure. Designated as Scotch-Weld EC-1751, EC-1838 and EC-2054, they are used for high strength metal and plastic structural bonding applications where heat and/or pressure are not feasible in the bonding operation. All three adhesives maintain high strength properties over a temperature range of −67 to 160F. Shear strengths of metal to metal assemblies bonded with these adhesives range from 2300 to 3200 psi at 75F. The two component modified epoxy adhesives are said to have high creep resistance under constant stress, exceptional adhesion to metals and plastics and good resistance to water, hydraulic oil and aromatic fuels. Minn. Mining & Mfg. Co., St. Paul, Minn.

Write No. 591 in Box on Inquiry Card

Epoxy Laminate

Glass base epoxy laminate maintains over 50% of its flexural strength at 150C temperature without any loss of its high electrical and mechanical properties. The material is available in 40″ x 48″ sheets, copper clad or unclad strips, blocks or in fabricated parts. Thicknesses range from 1/32″ to ½″. Spaulding Fibre Co., Inc., Tonawanda, N.Y.

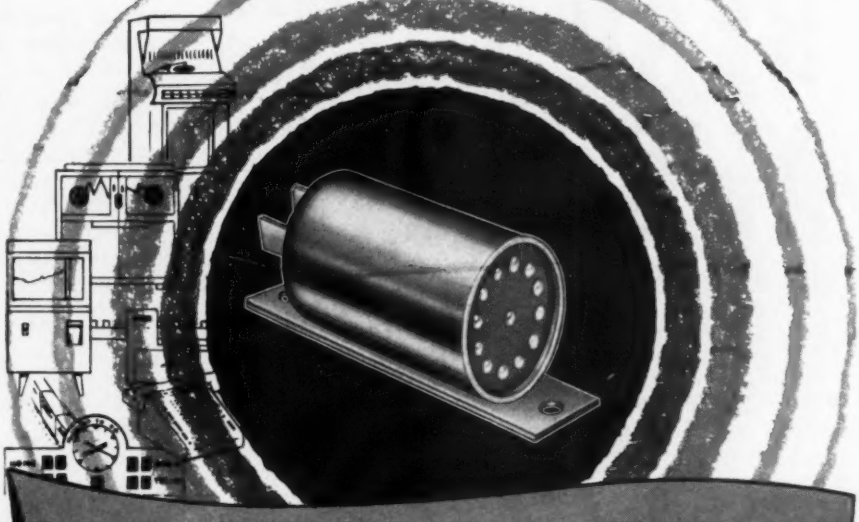
Write No. 592 in Box on Inquiry Card

Flexible Epoxy

Specifically formulated for the coating of printed circuit boards, a flexible epoxy (100% solids) is said to insure the reliability of the boards by sealing and reinforcing components, preventing insulation failure due to moisture or dust contamination, improving thermal shock resistance and acting as a vibration damper. Electronic Production & Development, Inc., Hawthorne, Calif.

Write No. 589 in Box on Inquiry Card

"an entirely new concept in stepper design"



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6 or 12 positions

for .... Business Machines • Computers
Vending Controls • Model Trains—Planes • Lighting Controls
Automated Devices • Counting Devices • Sorting Devices

● Now—a radical departure in stepper design provides new opportunities for applying the stepping relay principle over a far wider range than ever before.

1. **High Contact Rating.** 3 amps resistive, 1 amp inductive (50% P.F.) made possible by contactor action, dual make-break, positive circuit isolation contact mechanism. A revolutionary development, the Rotomite stepper eliminates wiping contacts, bridged circuits and, in most applications, slave relays.
2. **Continuous Duty**—from 3 to 230 v.d.c.
3. **Production line design**—completely metal clad—needs no special protection on the line. Shrugs off impacts of careless handling and is also unaffected by dust or metal particles.
4. **Continuous rotation**—up to 30 steps per second. No reset in present production items which include: D.C. continuous duty; A.C. intermittent duty; A.C. continuous duty now in development stage.
5. **Life:** Well in excess of 1,000,000 operations.
6. **Size:** 2″ long and 1 1/16″ in diameter. Weight: approx. 4 oz. Cost? Incredibly low! Write on your business letterhead for quick sample service and detailed information about the "Rotomite" midget stepper.

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MANUFACTURING COMPANY
1562-A CARROLL AVENUE *"Everything Under Control"* CHICAGO 7, ILLINOIS
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FOR CONTROL OF THE FUTURE

CIRCLE NO. 25 ON INQUIRY CARD

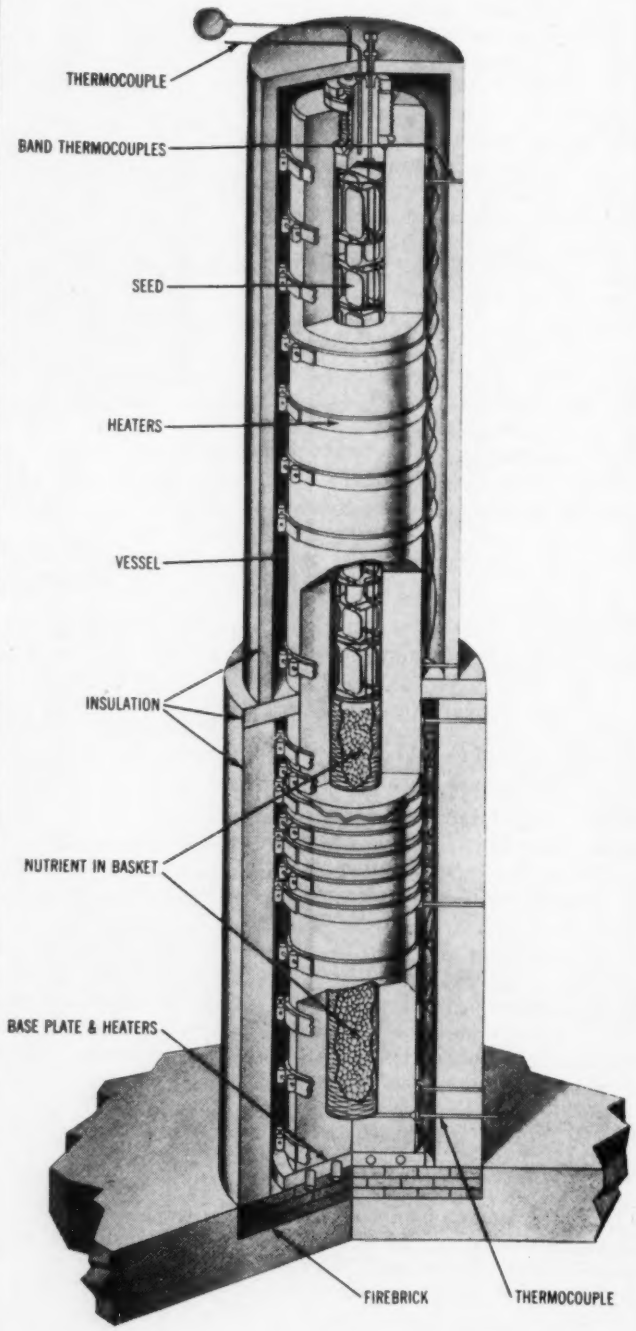
MATERIALS

SYNTHETIC QUARTZ

Low-Cost Crystals Can Be Made In Almost Any Quantity and Size

Full-scale mass production of syntheic quartz crystal at Western Electric, No. Andover, Mass., marks the successful climax of more than 50 years of experimentation and research. The synthetic quartz, superior in size and quality to natural crystals, grow in a sort of scientific rock garden, under tremendous pressure and fierce heat.

Twenty cylindrical vessels, each about ten feet long and a foot in diameter, are sunk below the surface of the floor.



A cutaway view of one of the vessels is shown in Fig 1. Into each vessel is lowered a long wire basket. "Seed" crystals of natural or artificial quartz are suspended in tiers at the top of the basket. The lower half of the basket is filled with small, inexpensive pieces of natural quartz. In this form, quartz is readily available from many sources but is unsuitable for electronic applications.

To begin the growth cycle, a weak alkali solution is poured into the vessel, which is then sealed. The contents of the vessel are heated to a temperature of 700 degrees and the interior pressure reaches about 25,000 pounds per square inch. It takes about three weeks of continuous growth to produce a harvest of crystals. Under heat and pressure, the small pieces of quartz at the bottom of the basket dissolve into the alkali solution. Crystals of quartz are re-deposited from solution and slowly build up on the "seed" plates at the top of the basket, where the temperature is slightly cooler.

While quartz in a variety of forms is the world's most common mineral, the pure, colorless crystals required for electronics cost about $30 a pound in the natural state. Imperfections found even in the best of natural crystals and waste from slicing operations results in a loss of about 97 percent of the material. This brings the cost of the quartz in the final plates used for electronic purposes to about $94 an ounce. By comparison, gold costs $35 an ounce.

Not only does the hydrothermal process for growing artificial crystals cost but a fraction of the price of natural crystals, the artificial variety contains fewer imperfections. Dimensions can be controlled and much more of each artificial crystal is usable.

Officials at Western Electric estimate that, at present, the yield per pound of synthetic quartz is at least 2½ times that of natural. With reduced cost of the crystals, there is a possibility that they may find wider application in electronic and electromechanical equipment.

According to company officials, Western Electric has already granted license on the process and will talk to other interested potential licensees.

←

Fig 1 Western Electric's hydrothermal process for growing quartz crystals depends on the maintenance of a critical temperature differential between the nutrient area (lower zone) and the seed plate area (upper zone). The nutrient (low grade quartz) dissolves in the hotter lower region and is carried by convection to the cooler upper region. Lower temperature here supersaturates the nutrient solution, causing the dissolved quartz to redeposit onto the seed plates in single crystal form. To maintain precise temperature control, it was necessary to have strip heaters spaced along the entire length of the vessel. It was also decided to reduce insulation over the growing zone in order to promote heat loss. Since the growing end is cooler than the lower zone, the external heat can be automatically controlled in the electrical power supply. Thus, with separate control over the heat supplied to the two zones, the temperature differential can be controlled precisely. Each zone's heaters are tied to a common power supply. Thermocouples are located in wells at the bottom of the vessel and in the closure, extending to within ¾ inch of the inside surface. Each thermocouple can control the heat input to its zone to accuracies well within limits specified for the process. With positive temperature control, reliable closure and built-in safety devices, the entire growing process, with the exception of loading and unloading, is completely automatic.

How To Assure
THE MAXIMUM
In High Response Clutch-Brake Systems

The clutch-brake unit you use must provide these basics:

1. minimum armature transfer distance between the brake and clutch housings.
2. clutch and brake friction surfaces held to a high degree of parallelism.
3. no backlash between armature and shaft.
4. clutch and brake friction facings burnished to give rated torque on installation.
5. closely held tolerances and finishes on all important surfaces.
6. minimum armature inertia without any sacrifice in mechanical strength.
7. magnetic circuit ability to respond to the field-forcing technique mentioned below.
8. positive armature release through absence of metal to metal contact and built in return action.

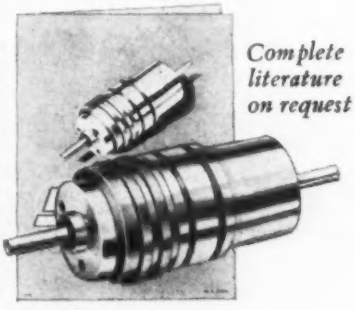
Because of the exclusive patented diaphragm, these features have been built into Simplatrol electric clutches and brakes.

The electric circuitry employed determines to a large extent the clutch reaction time. Reaction time is ordinarily reduced when a high momentary over-voltage is supplied (i.e., a voltage considerably in excess of the steady state rated voltage). Simplatrol can provide helpful suggestions on circuitry. Time required to bring load up to speed is a function of load inertia, r.p.m., and the torque of the clutch-brake.

Simplatrol's engineering organization will work with you to accomplish maximum speed, smoothness and quietness in your clutching and braking. Ask about applications of standard and custom designs in Simplatrol Electric Clutches and Brakes.

Investigate the total efficiency and economy of operation of the single complete unit, in torque ratings of 10 ounce inches to 470 pound feet, in sizes from ⅞" dia. to 12½" dia.

See for yourself the unique advantage of the flexible diaphragm action . . . the *only* moving part in a Simplatrol unit. Get the facts now on Simplatrol clutches and brakes.



Complete literature on request

Simplatrol products corp.
24-9 SALISBURY ST., WORCESTER, MASS.
Representation in Key Industrial Areas

971-0

CIRCLE NO. 26 ON INQUIRY CARD

TESTING

STROBOSCOPIC TAC

High White Light Intensity and Short-Duration Flashes Provide Sharp Clarity of Minute Detail For Motion Analysis.

Applying new design and packaging techniques to a well-known stroboscopic tachometer, Michael J. Fitzmorris, Dev. Engr. at General Radio Co., West Concord, Mass. has come up with a more effective tool for the study of motion in not only conventional machines but also in today's high-speed and miniaturized mechanisms such as servos, tape recorders, transducers and similar devices.

Improved performance characteristics of the new Strobotac (Registered Trademark) make stroboscopic techniques applicable in many new fields.

A new Strobotron lamp, developed by Edgerton, Germeshausen & Grier, provides three important improvements:

- A white light flash, rather than the red in the previous model, produces higher contrast in the viewed image and makes objects appear in their natural colors. Also, finer detail can be seen in white light with less strain.
- Higher light intensity, over 70 times as bright, allows effective use under normal room-lighting conditions and also allows objects deep inside a machine to be adequately illuminated.
- Shorter flash duration, by a factor of 10 to 20—0.8 μsec at high flashing rates—allows a corresponding increase in the upper limit of speed of the viewed object.

Supporting the above are other major improvements in electrical performance and mechanical design which contribute greatly to the utility, adaptability, and ease of handling of the new Strobotac.

- Higher frequency range—from 110 rpm to 25,000 rpm in three ranges—permits direct measurement of 400-cycle devices.
- Simplified controls—direct-reading rpm dial requires no multiplying factors, and only the range scale in use is visible.
- Sensitive input circuit is easily triggered by an external mechanical contact or electrical signal—only 6 volts, peak to peak, required.

Previous Strobotac Model

New Compact Strobotac

Fig 1 The large number of times the old instrument was damaged due to the fact the lense and the knobs were protruding outside the instrument was eliminated by providing a cover for the instrument which is fixed to the case. Cover also doubles as a stand for the instrument so that it can be set up easel fashion for use on the bench. The long cord is permanently attached to the instrument of the new Strobotac and is stored within the instrument by wrapping it around the range knob and the reflector and securing it by means of a special dummy plug. Lamp arm is hinged to provide 180 degrees of travel, and the reflector rotates 360 degrees around a second perpendicular axis to provide free aiming of the light beam. Reflector is securely held to the lamp arm by means of a spring-loaded detent button which allows the reflector to be removed easily for replacement of the lamp tube. A small amount of dispersion is built into the surface of the reflector, so that a nearly uniform light pattern is produced over the 10 degree width of the light beam. Calibration is accomplished with a neon bulb rather than the vibrating reed used in the previous model. One element of the neon bulb is excited from the powerline voltage and the other element from the voltage across the lamp tube. As the flashing rate of the lamp tube approaches either the fundamental or a harmonic of the powerline frequency, the neon light intensity will vary equal to the difference frequency.

- Neon calibrating lamp is located on panel, so that calibration can be easily checked at many speed settings.

EXTERNAL TRIGGERING

The internal oscillator is a free-running, amplitude-sensitive, bistable circuit that is a modification of the familiar Schmitt circuit which uses the charging voltage on a capacitor to determine the flashing rate of light. When the range switch is set in any of the external input positions, the timing capacitor is bypassed and the plate load changes in one half of the circuit. This converts the circuit to a conventional amplitude-sensitive Schmitt circuit so that the instrument can be triggered from relatively low level electrical input signals as well as mechanical switches. An input signal of at least 6 volts, peak to peak (2 volt rms sinewave signal down to 5 cps) is necessary.

Output from any type of electrical transducer such as photo cells, magnetic pickups and the like, can be synchronized with the flash of the Strobotac. It is also possible to use electrical time delay circuitry to delay the flash for some period after the initiating pulse is received. This feature is important when trying to look at a fast operation which has a very low repetition rate. For example, to look at the operation of a shearing machine in slow motion during the actual shearing of the metal piece, the Strobotac could be stopped initially by means of a magnetic pickup, then actuated when the shear starts its motion downward. The flash is delayed the proper time so that the shear is observed in operation as it goes through metal. By changing the amount of time delay the shearing operation is seen in slow motion.

UNIQUE CAPACITOR DESIGN

The Strobitron tube has 6 trigger electrodes spaced evenly between the main anodes of the tube. These trigger elec-

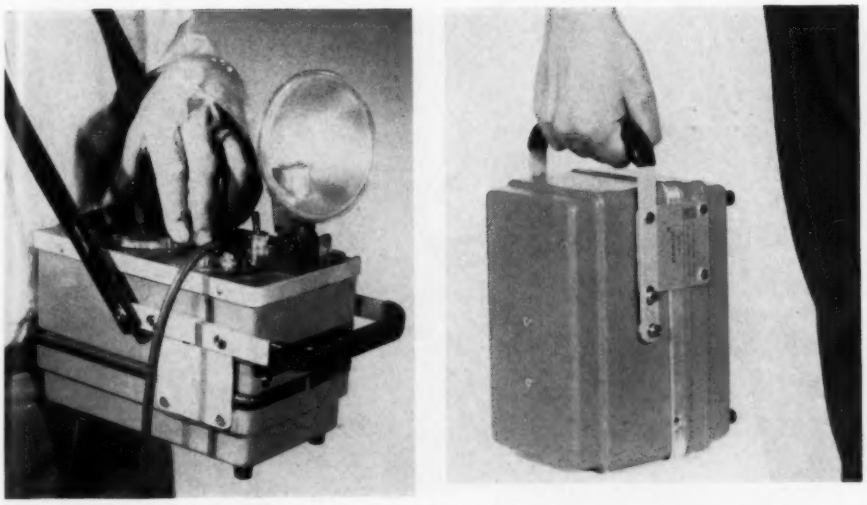


Fig 2 (Left) A neck strap is provided that can be easily fastened to the case to relieve weight on operator and free operator's hands for other functions. (Right) Closed flip-tilt case protects reflector and controls during transit.

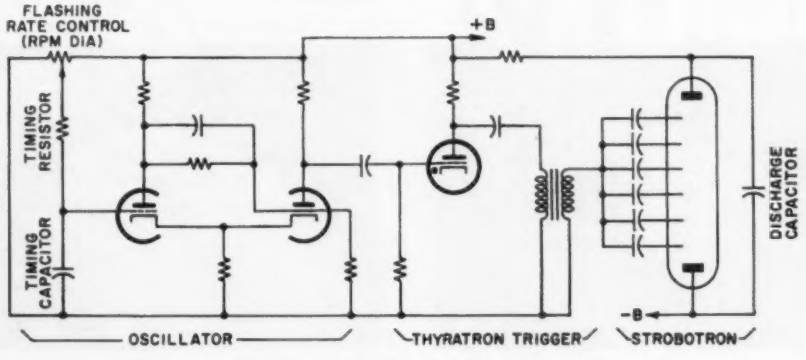


Fig 3 Elementary schematic of the circuit used in the new Strobotac. The frequency at which the oscillator circuit operates is determined by a resistor-capacitor combination connected to the input and a variable dc voltage. When the dc voltage is changed, the charging rate of the capacitor and the time between output pulses change. The flashing-rate control (rpm dial) is a potentiometer which varies the dc voltage to produce a flashing-rate range of 6.25:1. The rpm scale is essentially linear with dial rotation. A 6-to-1 change in frequency is obtained between ranges by a corresponding change in the timing capacitor. Trimming resistors, set at the factory, are used to correct for small variations in capacitor values so the three ranges track properly. Although the upper limit of the oscillator is 25,000 rpm, or approximately 420 cps, external triggering is usually possible at frequencies as high as 45,000 rpm (750 cps). The upper frequency limit depends on the characteristics of the individual Strobotron tube and will appear either as erratic operation of the tube or the formation of a low-intensity, continuous arc, called "hold-over." For triggering by a mechanical contactor, part of a dc voltage divider is shorted by the contactor to generate the signal into the Schmitt circuit. Since a positive-going signal is necessary to produce the correct polarity trigger to operate the Strobotron, the light flash occurs on the opening of the mechanical contact, rather than on the closing. Because the time between opening and closing of the mechanical switch is usually sufficient for the Strobotron circuit to recover, care should be taken to eliminate contact bounce, which will produce unwanted flashes.

trodes are fired from a 3-4,000 volt pulse and an arc is generated to cross the arc gaps essentially between these electrodes. As each electrode fires successively it is necessary to capacitance-couple these electrodes from the pulse transformer. In order to reduce the high voltage capacitor size normally required for this purpose, Mr. Fitzmorris used the pins on the tube socket as one plate of the capacitor and the brass slug in the center of the tube socket as the other plate of the capacitor. A ceramic cup around the brass slug, with a tight fit between the slug and the pins, serves as the dielectric. It was possible, therefore, for Mr. Fitzmorris to obtain six high-voltage capacitors in a small space actually no larger than what would normally be required in the mounting of the tube socket in the lamp and made possible the small swivel support assembly which contains the lamp.

IMPROVED PACKAGING

In designing the mechanical package, Mr. Fitzmorris' goal was to remove most of the limiting characteristics of the old Strobotac determined during the 25 years it has been use. In the previous model, the light and the dial were fixed with respect to one another therefore the proper positioning of the lamp frequently meant that the dial was not in a convenient location to be read. In the new unit, the light can be moved with respect to the panel on which the dial is located. By means of a swivel, the lamp assembly rotates 180° with repect to the panel and the reflector rotates 360° around the light.

The width of the case was designed so that it can be easily held in one hand thus avoiding the use of a handle as in the old Strobotac. Although there are more components in the new unit, by properly designing the layout of the components within the rack, Mr. Fitzmorris reduced the volume of the new unit by approximately ⅓ that of the old unit. Weight of the new instrument was also reduced by approximately 2 lbs.

SOME TYPICAL APPLICATIONS

Since the Strobotac operates satisfactorily from 400 cycle power lines as well as from 50-60 cycle lines, it can easily be used in aircraft applications. In the measurment of speeds of fractional horsepower motors, Strobotac requires no mechanical or electrical connection

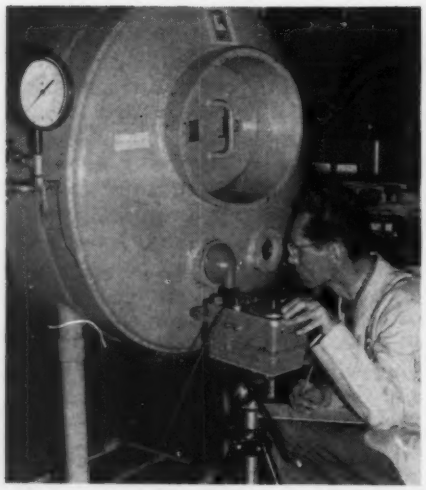


Fig 4 At Rotron Mfg. Co., a technician examines the performance of a fan operating in heavier-than-air sulphurhexafluoride. Brighter light, and the new Strobotac's "long-throw-beam" illuminate the test unit through a small porthole. The fan's speed and performance under pressure are observed by the operator through a second window. Rotron uses Strobotac as the principle test instrument for speed measurements and the analysis of structural weaknesses of air-moving devices. In developmental units, fan blade resonances are detected visually while subjected to vibration on shake tables. Other laboratory work includes dynamometer measurements and air-delivery tests in which it is important to measure speed accurately under pressure.

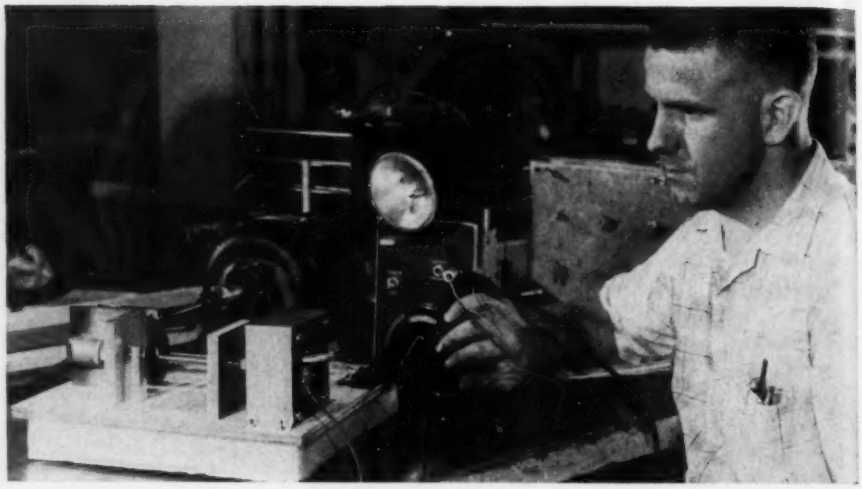


Fig 5 Strobotac at Acton Laboratories, in a torque-measuring setup, tests right-angle mechanical drives. A fractional hp motor powers the drive which has a magnetic solenoid clutch as its output load. The drive's output shaft is a gauge which indicates torque directly on a calibrated dial. Since the dial rotates with the shaft it must be "stopped" for torque readings. Strobotac's microsecond flash eliminates blur, permits reading as easily as though the fine-dial calibrations were standing still, and allows Acton technicians to check a wide variety of dynamic conditions quickly and conveniently.

to the motor and its usable accuracy of one percent makes it ideal for this use.

Measurements are made to determine: normal operating speed, speed variation due to line-voltage changes, speeds at various conditions of overload and underload, torque-speed characteristics, and critical speeds at which vibration occurs. By slow-motion observations, brush action can be studied, and and chattering caused by commutator eccentricity as well as vibration of frame and parts can often be detected.

Measurement of torque with the Strobotac is a widely used technique. When the motor and load shafts are connected by an elastic coupling, and the rotational motion is stopped by the stroboscope, the position of a pointer on the spring coupling will change as the driven shaft is loaded. With the addition of a calibrated scale, the system becomes a torque meter.

The ability of the new Strobotac to measure high frequency without distortion can be applied to the study of

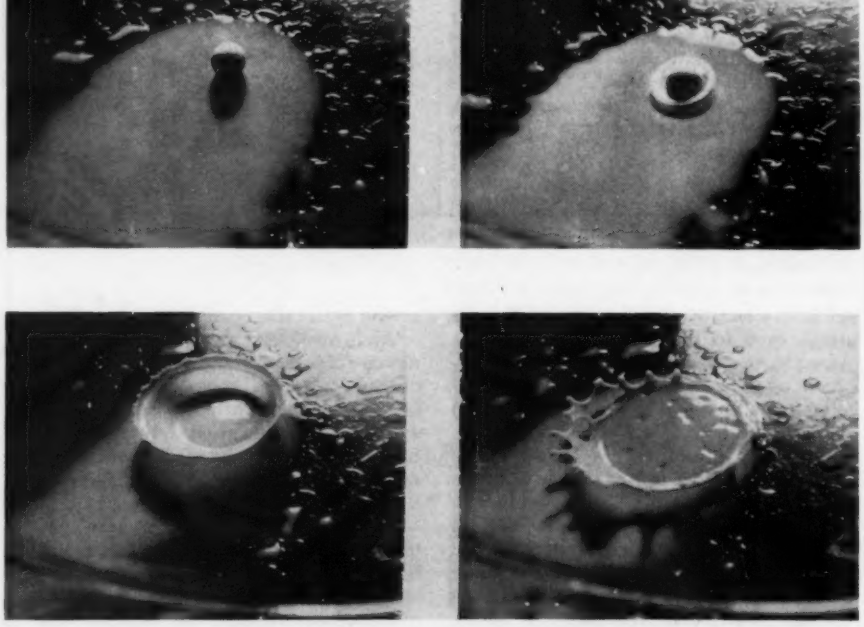


Fig 6 Four successive views of a drop of milk landing on a metal plate were photographed while illuminated by General Radio's new Strobotac. Ability to trigger the Strobotac from external electrical signals greatly simplifies the technique required to synchronize the flash of the Strobotac with the operation of high-speed cameras. Because of the narrow beam of the Strobotac, the amount of area that is illuminated is somewhat restricted. However, if the desired picture is of a relatively small area, it is possible to use any of the Polaroid films or high-speed films from ASA200 and up to obtain satisfactory pictures with any of the standard flash intensities. The small width of the Strobotac's light pulse enables the taking of pictures of relatively high-speed motion.

motion in tape-recorder mechanisms, relays, servos, and transducers of all types. Speaker voice-coil clearance, spider flexing, and cone performance are all susceptible to stroboscopic observation.

Vibratory motion and its effects can be readily studied with the aid of the very short light pulse from the Strobotac. Displacements in vibrating parts can be measured accurately with the aid of a microscope and cross hairs.

Another important use is the detection of resonances in devices subjected to the cyclic forces produced by shake tables. Relays, fans, motors, and electronic equipment and systems—large and small—are subjected to the "dithering" action of shake tables while the sharp definition of the stroboscopic light is used to detect damaging self-created, vibratory conditions.

Ability to trigger the Strobotac from an external electrical signal greatly simplifies the techniques required to synchronize the flash of the Strobotac for single-flash photography. The output of a photocell or microphone, amplified if necessary, can be used.

Among other applications are the dynamic balancing of rotors, study of slip between friction-driven members, determination of the speed at which jaws of centrifugal clutches begin to open and the calibration of watt-hour meters.

A complete list of the possible uses of the Strobotac would take many pages. The instrument is useful just about anywhere there are machines and moving mechanisms.

Write No. 160 in Box on Inquiry Card

Temperature Chamber

For use with standard tensile test equipment. Test chambers are custom-tailored to specific applications. The heavy aluminum chamber provides a test area 22″ high x 7″ wide x 8″ deep. Two one-inch ports with special plugs give access for all standard grips. A frost-free, multipane window permits visual inspection at all times. Specimens can be tested under temperatures from −120 to +300 F. Cincinnati Sub Zero Products, Cincinnati, O.

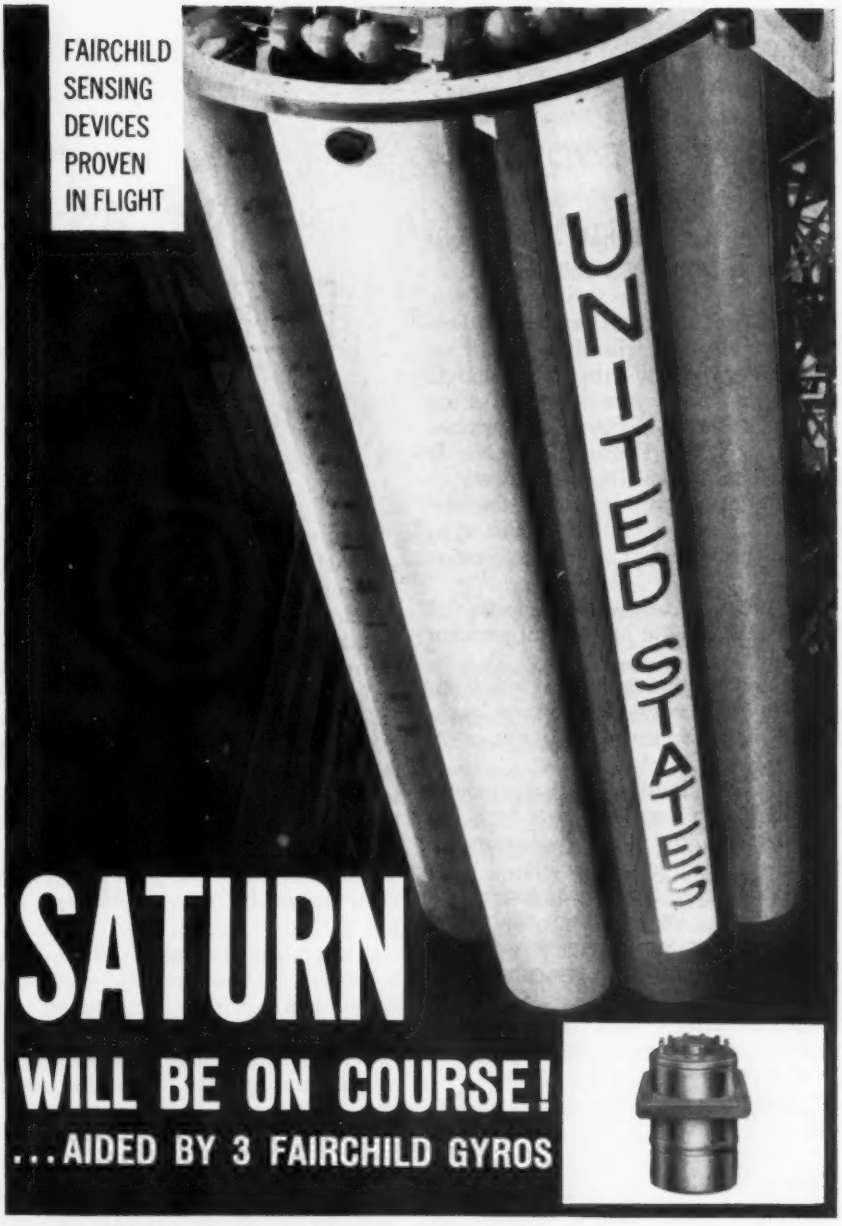
Write No. 764 in Box on Inquiry Card

Strain Gage Indicator

Designed for maximum versatility as a research tool, an indicating or recording strain gage accommodates all commonly used gage factors, gage resistances, and transducer bridge configurations. Eight calibrated sensitivity ranges cover all normal requirements. Maximum resolution: better than one microinch per inch; accuracy of panel meter indication: 1% of scale. Daytronic Corp., Dayton, Ohio.

Write No. 751 in Box on Inquiry Card

FAIRCHILD SENSING DEVICES PROVEN IN FLIGHT



SATURN WILL BE ON COURSE!
...AIDED BY 3 FAIRCHILD GYROS

This is the huge Saturn Super-Booster under development for the National Aeronautics and Space Administration at Redstone Arsenal, Alabama. Consisting of eight H-1 liquid propellent engines with a combined thrust rating of 1.5 million pounds, it will be four times as powerful as the largest group of engines available to the free world today. When assembled with second, third, fourth and possible fifth stages, Saturn Super-Booster will be able to put several tons of instruments on the moon.

Each mammoth Saturn vehicle may have three sub-miniature FAIRCHILD RG-101 RATE GYROS at the heart of the main control system. Now under evaluation by NASA at Huntsville, each of these thimble-sized gyros (weighs only two ounces) measures rates about one of three mutually perpendicular axes—generates anticipatory corrective signals to keep Saturn on course.

Built to the most demanding specifications, these RG-101 floated gyros represent the most advanced state of the art—another reason why Fairchild is the foremost manufacturer of high-performance precision sensing devices.

Fairchild RG-101 floated rate gyros are the smallest made by anyone! And the most rugged!—Only 1 5/16″ diam. x 1 5/8″ long. Withstand 150 g's of shock and 30 g's vibration to 2000 cycles without damage, over the entire design range 5 degs./sec. to 1000 degs./sec. max. rate. Threshold rate is less than .025 degs./sec. Self-test capabilities for easy remote checkout. Gimbal system's freedom of movement can be checked over entire range of travel, from limit stop to limit stop in most designs. Friction or threshold level, sensitivity, and even damping ratio can be checked from the blockhouse. Run-up time is less than five seconds, using over-voltage techniques.

Fairchild components . . . built and tested beyond the specs for Reliability in Performance.

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GYROS
PRESSURE TRANSDUCERS
POTENTIOMETERS
ACCELEROMETERS

CIRCLE NO. 27 ON INQUIRY CARD

AUTOMATIC SERVO TESTING

Unit Plots Bode, Nichols and Nyquist Responses Within 12 Minutes

Determining servo performance quickly, accurately and with a degree of repeatability were the design objectives which led to the development of an Automatic Servo Plotter at Republic Aviation Corp., Farmingdale, N. Y. David Rice, Senior Group Engineer at Republic Aviation, described the design and operation of the instrument in a paper presented at the 1960 Wescon Show.

Mr. Rice briefly summarized the tasks the automatic plotter can perform as follows:

- Generates ac or dc quadrature input signals for network and servo component testing from 0.3 to 30 cps in 40 steps.
- Extracts fundamental, harmonic-free phase and amplitude data from the component output signal by means of cross-correlation rms detectors.
- Performs necessary conversions to log frequency, log amplitude and polar coordinates for various types of plots.
- Provides graphical presentation of data over a 40 ± IDB (100:1) log amplitude range, and continuous 4 quadrant ± 2 degree phase range, in 40 discrete frequency increments.
- Selects half-decade expanded scales.
- Self-tests for phase or amplitude response.
- Utilizes self-adaptive servos to compensate for gain change in phase and amplitude computers.
- Completes any one of the three plots (Bode, Nichols or Nyquist) automatically within 12 minutes.

DESCRIPTION

The laboratory version consisted of five basic chassis: suppressed carrier generator, correlation detectors, computer, X-Y plotter, and the programmer. For dc servo or network capability, a modulator and demodulator package was added making a total of seven chassis. Functional relationship is illustrated by the simplified system signal flow diagram in Fig 1.

Suppressed carrier quadrature signals from the generator are frequency controlled by the programmer. These signals simultaneously feed the component-being-tested and the detector reference channel. Output from the component goes to the detector signal channel where it is separated into phase and amplitude quantities.

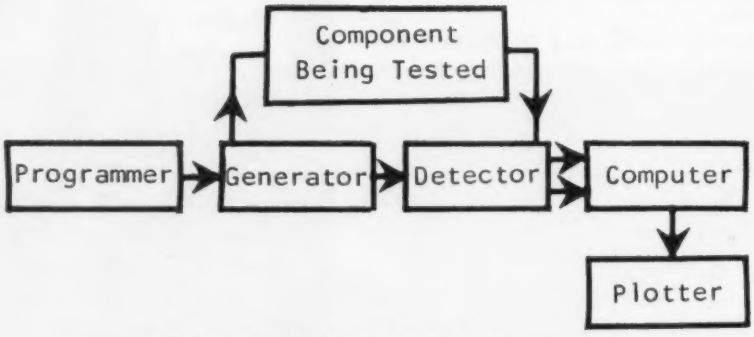


Fig 1 Simplified signal flow diagram of Republic Aviation's Automatic Servo Plotter.

The computer then prepares this information for a specific type of plot on instruction from the programmer. An X-Y plotter graphically portrays the result in rectangular or polar form. Voltage proportional to the log of frequency, supplied by the programmer for Bode plots, is accurately adjusted by means of potentiometers in a series bleeder circuit, switched up or down ½ decade after ten plot points have been scanned. This is illustrated in Fig 2.

A thyratron controlled motor drives a 400 cps resolver from 0.3 to 30 rps. Fixed and variable quadrature suppressed carrier signals are available on one AN 3102A chassis connector. All outputs are isolated by buffer amplifiers.

DETECTOR AND COMPUTER

Interaction of the detector and computer units is shown in Fig 3. An ac (or modulated dc) servo signal enters the detector where it is split into 2 channels: phase and amplitude. The phase signal is gain controlled by means of a hyperbolic potentiometer to within 3 db, and cross-correlated with a reference in a null-seeking servo loop. The shaft output then represents fundamental phase shift of the signal from its reference and is read out on a linear pot for Bode and Nichols plots or converted by a sin-cos pot for polar plots (Nyquist). Positioning of the resolver in this channel also serves to maintain a signal-matched phase reference signal for the amplitude channel similar in function to the automatic gain control in the phase channel. This self-adaptive feature is further enhanced by utilizing the sinusoidal variation in the output of a rotating resolver such that where the slope is maximum, a null is sought and where the slope is zero, a maximum is sought.

In the amplitude channel, the signal is cross-correlated in a similar manner except that the shaft output is propor-

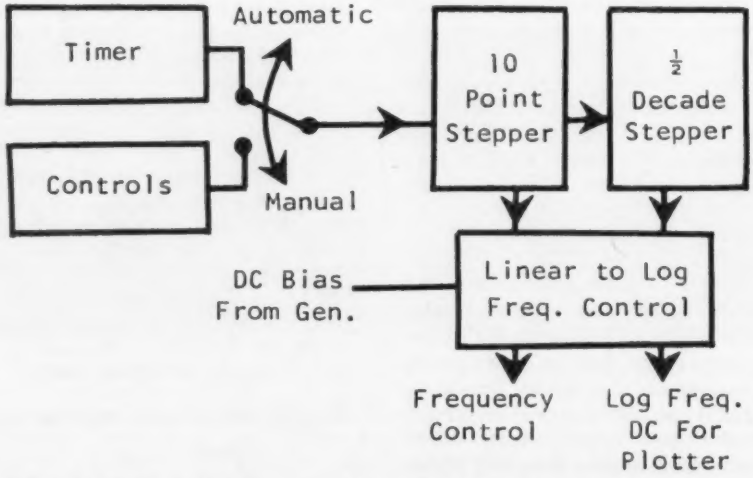


Fig 2 Flow diagram of the programming unit. All necessary front panel controls for the Automatic Servo Plotter are located on the programmer chassis. These include, in part, type-of-plot switch, expanded range for Bode plots, manual-automatic scan switch, frequency up-down switch, on-off and others.

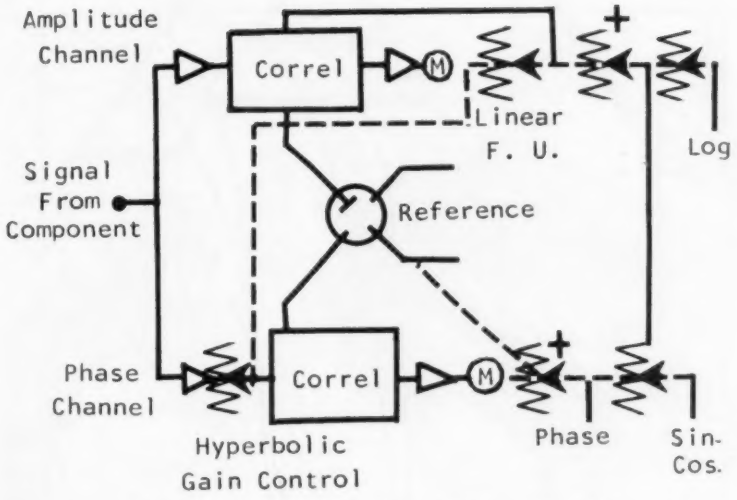


Fig 3 Schematic of the detector and computer units.

tional to the input. Again, only the fundamental component of the input signal is passed through. Shaft information is then converted to a dc voltage proportional to the log amplitude for Bode and Nichols plots, and to linear vector amplitude for polar (Nyquist) plotting.

Analogs of all the necessary variables have now been separated and filtered, ready for plotting. It is felt that the information, due to its inherently harmonic-free characteristics, can be used for graphical displays of the describing function for non-linear systems.

A conventional X-Y plotter is used to display information. All voltages feeding the two axes are programmed and scale-factor corrected so that there is no adjustment required in going from one type of plot to another. The response time of pen positioning is kept to a minimum by making a 40 point plot such that small motion is required between points. Due to the log frequency conversion, it is possible to use standard oscillograph or pen-type recorders for the phase and amplitude responses in Bode plot. Typical Bode plot of amplitude response is shown in Fig 4.

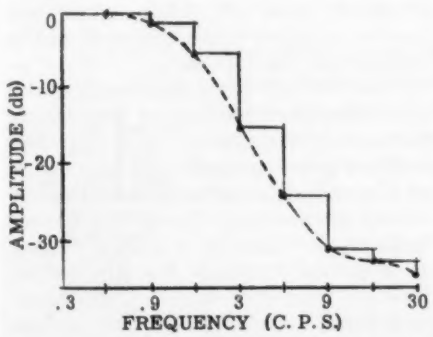


Fig 4 Typical Bode plot of amplitude response. Step height is directly proportional to the slope of the response such that break points can be identified quickly.

SELF-TEST OPERATIONS

Checking the instrument is easily done by using four specific bits of internally generated signals:

- Reference signal for full scale amplitude 10 volts).
- Reference signal at –20db (1 volt).
- Reference phase at zero degrees.
- Reference phase at –180 degrees.

The instrument can plot its own frequency response in phase or amplitude or both. These functions can be activated by front panel switching.

APPLICATIONS

While this instrument has been used on various aircraft servo systems and networks, Mr. Rice believes that the concept can be applied equally to gyros, actuators, regulators, fire control, industrial automatic machines and other equipment. He noted that more work must be done on showing its application to non-linear systems analysis using Describing Function Techniques. Mr. Rice indicated that a list of compensation networks and their associated Bode, Nichols & Nyquist graphs, which should prove useful to servo design engineers, is now being prepared. From his experience with the performance of the Automatic Servo Plotter, Mr. Rice feels that a low cost production type of Go-No-Go tester for servos is certainly feasible.

Write No. 175 in Box on Inquiry Card

Variable Phase Standards

With an accuracy of ±0.50° or better, variable phase standards permit the phase between two self-generated voltages to be shifted to any desired angle. Instrument generates two signals of equal amplitude, differing in phase by any angle from 0 to 360°. The reference signal has a fixed amplitude of 50v rms. Vector output, which may be displaced in phase, has a maximum amplitude of 50v rms, and can be attenuated in steps of 50 mv within the range of 0-50v rms. Selector switch permits operation at any of three frequencies within the range of 150 to 3000 cps, variable ±5% max. Gertsch Products, Inc., Los Angeles, Calif.

Write No. 763 in Box on Inquiry Card

Temperature Recorder

Miniaturized temperature recorder is believed to have the first meter movement sensitive enough to permit temperature recording directly from a thermocouple without a signal amplifier. Maximum temperature span: 0 to 2500; accuracy: ±2 percent of full scale; standard chart speed: 1 inch per hour, other speeds also available. The recorder operates on the pyrometer-with-clamper bar principle. Assembly Products, Inc., Chesterland, Ohio.

Write No. 759 in Box on Inquiry Card

Chart Recorder

What is claimed to be the world's most compact, lightweight 8½" x 11" X-Y recorder features transistorized circuitry, measures 10½" x 16⅛" x 4½", and weighs 20 lbs. The portable instrument contains built-in calibrated X-axis time sweeps, plus 16 calibrated ranges on each axis, with an infinitely variable vernier. High input resistance, a self-contained vacuum paper hold-down, full range calibrated zero set and zero suppression on each axis, plus high recording speed are some of its characteristics. It can be used with ac/dc converter, log converter and other data handling and recorder accessories. F. L. Moseley Co., Pasadena, Calif.

Write No. 761 in Box on Inquiry Card

Phase Sequence Tester

Completely self contained for laboratory or field use, a tester determines phase rotation of 3-phase servo motors, generators and power supplies. No neutral connection required. Price: $15.95. Space Electrolabs Co., Lynbrook N. Y.

Write No. 753 in Box on Inquiry Card

COMPONENT LIFE-TESTING PROCEDURES

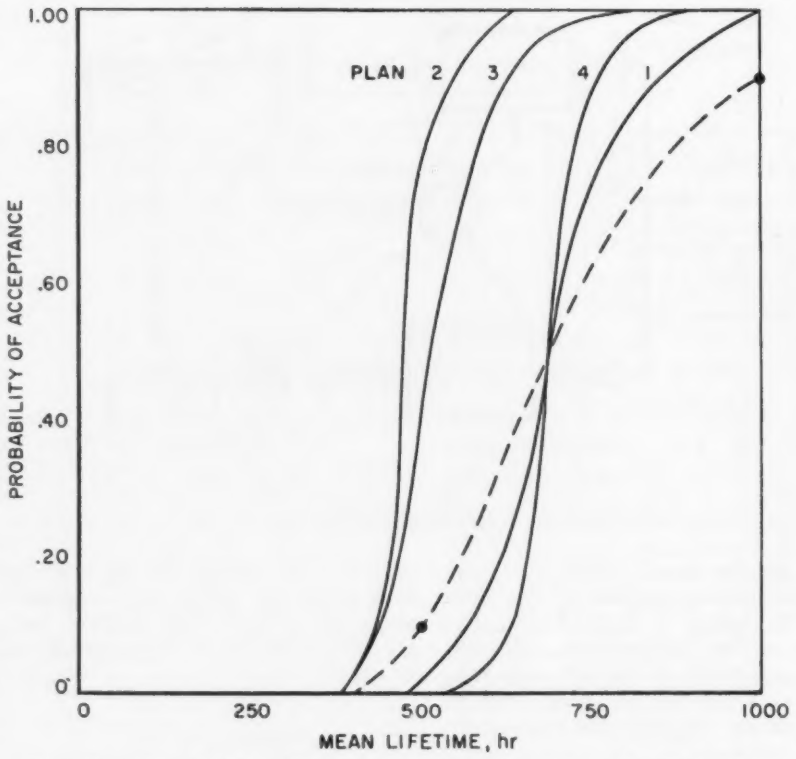
Study Reveals That Widely-Used Statistical Techniques are Very Sensitive to Departures from Initial Assumptions

Almost all statistical life-testing techniques are based on the assumption that the time to failure of components in a life test follow the exponential distribution. Since in practice the probability distribution of failure times may not be exponential, it is important to determine the robustness properties of these statistical life-testing procedures. (Procedures which can be used effectively when some of the underlying mathematical assumptions are not satisfied are termed robust.)

Robust procedures are particularly desirable in reliability prediction because the underlying mathematical properties of the observed phenomena may not be known. Recently, M. Zelen and M. C. Dannemiller of the National Bureau of Standard's Statistical Engineering Laboratory made a study of four acceptance sampling plans that are representative of life-testing procedures currently used in the electronics industry.

The four acceptance sampling plans which were investigated for robustness properties are: (1) Fixed sample size plan: a sample of n components is tested until all fail; (2) Fixed sample size plan with censoring: a sample of n components is placed on test, and testing is discontinued after the r^{th} failure ($r < n$); (3) Truncated nonreplacement plan: a sample of n components is placed on test and the testing discontinued after a preassigned time; (4) Simple sequential plan: the components are placed on test one at a time, and after each failure a decision is made to accept the lot, reject the lot, or continue testing.

For any one of these acceptance sampling plans, the operating characteristic (OC) curve can be constructed depicting the mean failure time plotted against the probability of acceptance. This curve is well known when the distribution of failure times is exponential. If it can be shown that the operating characteristic curve is not appreciably changed when the failure times actually come from certain alternative distributions, then the sampling procedure is said to be robust with respect to the alternative distributions.



Operating characteristic (OC) curves were computed at the National Bureau of Standards for four acceptance sampling plans based on the exponential distribution when the failure times actually follow an alternative Weibull distribution. If the exponential distribution applies, components having mean lifetimes of 1000 and 500 hours are accepted with probabilities of 0.90 and 0.10, respectively. This is illustrated by the dashed line, which is the OC curve for plan 3 when the failure times come from an exponential distribution.

The Bureau's scientists chose three Weibull distributions with different shape parameters as alternative distributions for studying the robustness of the four acceptance sampling plans. The Weibull distribution belongs to a class of distributions which characterize "wear out" failure as the longer the item has been in operation, the greater the probability of failure. Further, it is difficult to distinguish between the Weibull and the exponential distributions for small sample sizes. This latter fact has special significance because the experimenter will rarely have enough data to enable him to decide which distributional assumption holds.

Exact operating characteristic curves for plan 3 were obtained from known theoretical results; OC curves for plans 1 and 4 were calculated using special analytical approximations developed at the Bureau; OC curve for plan 2 was calculated by simulating several thousands of life-test experiments on a computer.

The operating characteristic curves indicate that not one of the four acceptance sampling procedures is robust with respect to Weibull alternative distributions. The fixed sample size plan with censoring (2) and the truncated nonreplacement plan (3) are strikingly nonrobust because of the particular choice of Weibull distributions in this study – components having a low mean failure time showed a high probability of acceptance. On the other hand, the fixed sample size plan (1) and the sequential plan (4), while not robust, are less sensitive to departures from the exponential assumption.

The Bureau's study demonstrates the risks taken by a test analyst who adopts an acceptance sampling procedure without possessing sufficient knowledge of the underlying properties of the observed phenomena. The results further indicate the need for research leading to statistical methods for life testing that are insensitive to distributional assumptions. Development of robust methods is one of the goals of the Bureau's program of mathematical research into the prediction of the reliability of complex systems. • • •

TO THE ENGINEER

who can't tolerate a lapse of memory

If you're working on a think machine that can't afford to break its train of thought, consider AE's pint-size, fast-stepping OCS switcher. Unlike electron tubes and relays, this sophisticated device won't lose stored memory in the event of power failure or circuit interruption.

Besides, it can do the work normally assigned to whole banks of relays.

The AE Series OCS will follow or initiate a prescribed series of events or cycles at 30 steps per second impulse-controlled, or 65 steps per second self-interrupted. Any programming sequence can be set up on one to six cams with as many as 36 on-and-off steps per cam. And each cam will actuate as many as six contact springs.

In any event, if your designs involve relays or stepping switches, AE circuit engineers may be able to save you a pretty penny. Or, if you'd like to leave the switching to us, we're equipped to supply prewired and assembled, custom-built control units, *or* help you develop complete control systems.

To explore the matter, just write the Director, Control Equipment Sales, Automatic Electric, Northlake, Illinois. Also ask for Circular 1698-H: *Rotary Stepping Switches;* Circular 1702-E: *Relays for Industry;* and our new 32-page booklet on *Basic Circuits.*

AUTOMATIC ELECTRIC GENERAL SYSTEM

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TESTING

Multi-Trace Oscilloscope

Simultaneously displaying up to eight waveforms on a vertically-mounted 17″ CR tube, a monitoring oscilloscope serves in multi-channel oscillographic recording systems where accurate event monitoring is desired. The number of traces on the 'scope screen depends on the number of gating amplifiers used —one amplifier for each Y-axis input. Repetitive and single sweep speeds of 5″, 2.5″ and 1.25″ per sec are provided in one model. For slowly varying waveforms, 25 sec single sweep is also available. Sanborn Co., Waltham, Mass.

Write No. 762 in Box on Inquiry Card

Vacuum Measurements

Recording ionization gauges with logarithmic outputs permit the measurement of vacua from 10^{-3} to 10^{-10} mm of Hg on a single scale without range changing. This single-scale feature enables long-term unattended operation — not only as a recording device but also as a monitor and control for automated processing over periods up to 200 hours. The Fredericks Co., Bethayres, Pa.

Write No. 754 in Box on Inquiry Card

Vibration Calibrator

A compact, 3¼ lb, battery-operated unit calibrates accelerometers, vibration pickups and vibration meters, and other vibration-measurment systems that use small, crystal-type accelerometers as sensing elements. Consisting of a transistorized electromechanical oscillator and a battery-operated cylindrical shaker, the instrument provides standard accelerations of 1 g (*rms*) at 100 cps. Acceleration accuracy: ±10%; frequency accuracy: ±1%. General Radio Co., West Concord, Mass.

Write No. 766 in Box on Inquiry Card

Digital Voltmeters

A multi-range, portable dc digital voltmeter contains a tape slidewire potentiometer whose resistance element is 144 inches long and calibrated and geared to an in-line counter for readout accuracy to 0.1% in normal ambient temperature. Calibration is better than 0.05%, resolution better than 0.02%. The servo-driven instrument requires no warm-up time. Suitable for all military and commercial requirements, models are available with a maximum of four ranges — the base range increased by a factor of 10 — with a minimum of zero to 0.020 vdc and maximum of zero to 10,000 vdc. Howell Instruments, Inc., Fort Worth, Texas.

Write No. 758 in Box on Inquiry Card

R, L and C Measurements

Employing a Wheatstone bridge circuit, an electrical parameter measuring instrument functions in the conventional manner when measuring dc, and is connected to a transistor amplifier with phase comparison when measuring ac. A transistor oscillator feeds 800 cps to the bridge. Resistance measurements: 0.05 ohms to 50,000 ohms dc; 50 ohms to 5 megohms ac; capacitance measurements: 5 pf to 50 microfarads; inductance measurements: 50 henries. It is capable of comparison tests when used in conjunction with external R, L, and C standards. Physics Research Labs., Uniondale, N. Y.

Write No. 752 in Box on Inquiry Card

Vibration Machine

Designed especially for testing small electronic components and assemblies in accordance with procedures described in MIL-T-19500B, reaction-type, environmental, vibration machines produces accelerations up to 25 G's continuous at nominal load. The machine is also suited to general testing applications where a wide frequency range, large excursions, high accelerations and continuous operation are required. Equipped with automatic controls for continuous unattended operation for periods of 100 hrs or more, the machine has a maximum load capacity of 50 lbs, nominal load of 30 lbs and a table mounting surface of 15″ x 15″. Maximum excursion: 0.375″ at nominal load; frequency range: adjustable from 10 to 100. L. A. B. Corp., Skaneateles, N. Y.

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High Frequency Meter

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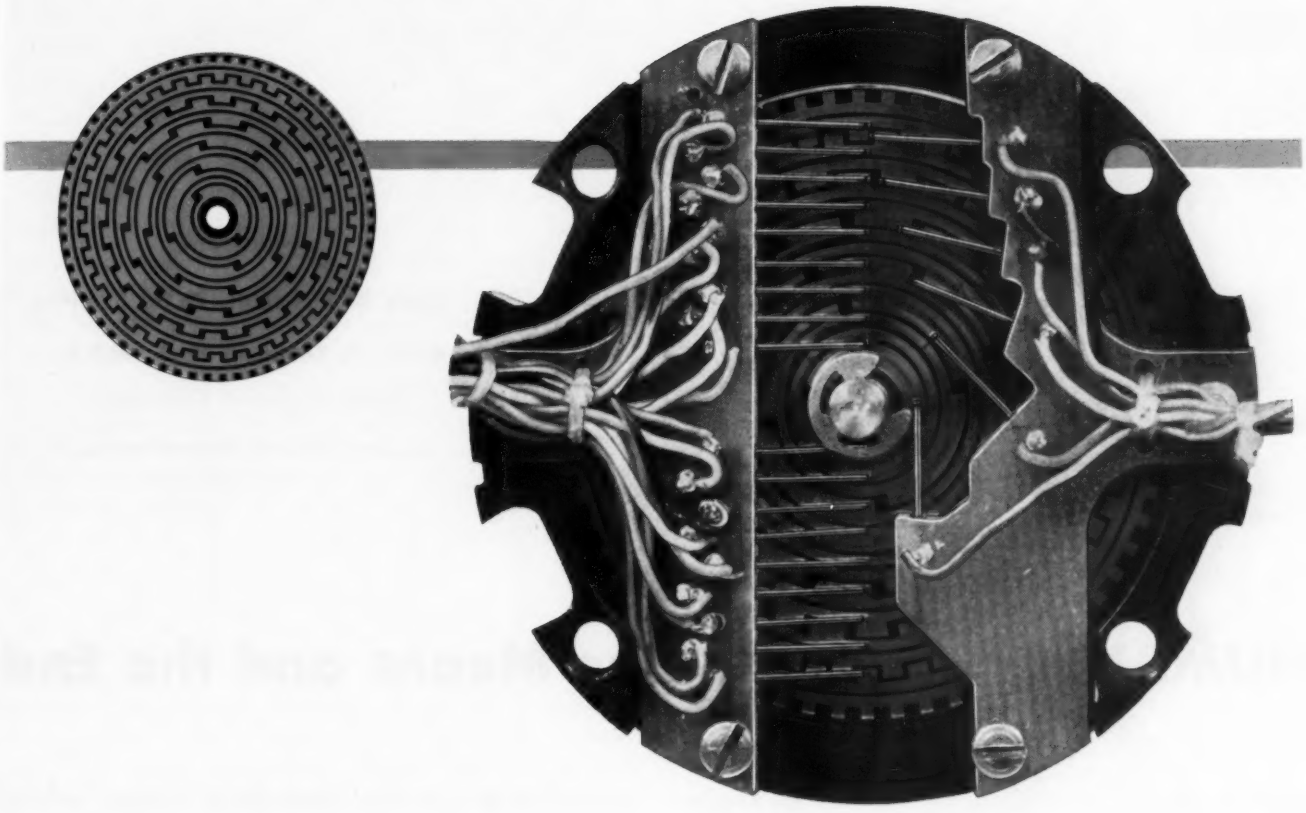

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MANAGEMENT

Lewis B. Klebanoff, Ph.D., S.M.Hyg.

Arthur J. Bindman, Ph.D., M.P.H.

Human Resources Consultants

Boston, Massachusetts

HUMAN RESOURCES - The Means and the End

Despite tremendous technological breakthrough and increasing automation of production, we shall never, on this planet, make obsolete the human individual as the essential creative force behind the machines or as the essential element in the values of industrial enterprise.

Consider, if you will for a moment, the tremendously complex machines which play such an important role in our society today. They are wonderfully intricate, precise and even "rational", and are protected with an array of valves, gauges, meters, thermometers, relays, fuses, etc. to maintain a continuous vigil on the pulse, temperature and "digestion" of these servants of man. Specially trained personnel hover over them to attend to their every wheeze, rasp, leak, stall or other failure, which symptoms might suggest a potential breakdown or disability. Tools, spare parts and detailed maintenance instructions are on a standby basis to provide everything from first aid to major surgery.

But what of the men, the people, the human beings, who created these machines, who refined and perfected them, who built them, who care for them, and who sell them? Is there comparable concern for their upkeep, for their preventive maintenance, for their first aid, and for their "fine tuning" to become more productive components of the industrial enterprise? Almost across the board there has been less attention paid to this area than to that of machine technology. This is not altogether surprising considering the disproportionate amount of money and effort that has gone into technological research in contrast to behavioral research. We must also be mindful of the special difficulties involved in doing research on live, very busy, normal individuals in their daily life situation as contrasted to laboratory research in either the physical or behavioral sciences. Despite these difficulties, much work has been done in recent years and there is an ever-growing body of knowledge which is even now applicable to the problems of the work situation.

Utilization of this knowledge has been hindered by several factors: (1) lack of understanding that such knowledge for dealing with human problems in industry does exist; (2) shortage of skilled psychologists who can meaningfully apply this knowledge to the industrial setting; (3) the general notion that this knowledge is merely "common sense" and intuitively known to anyone who "understands folks"; (4) some precipitous excursions into the field by unqualified or only partially qualified individuals who made lavish promises that did not hold up over time, and which may have served to disenchant those who originally held high expectations from such services. We propose in succeeding articles to discuss a number of areas in industry in which psychologists can play an important role in bringing this new knowledge to bear upon the problems of industrial management and personnel practices.

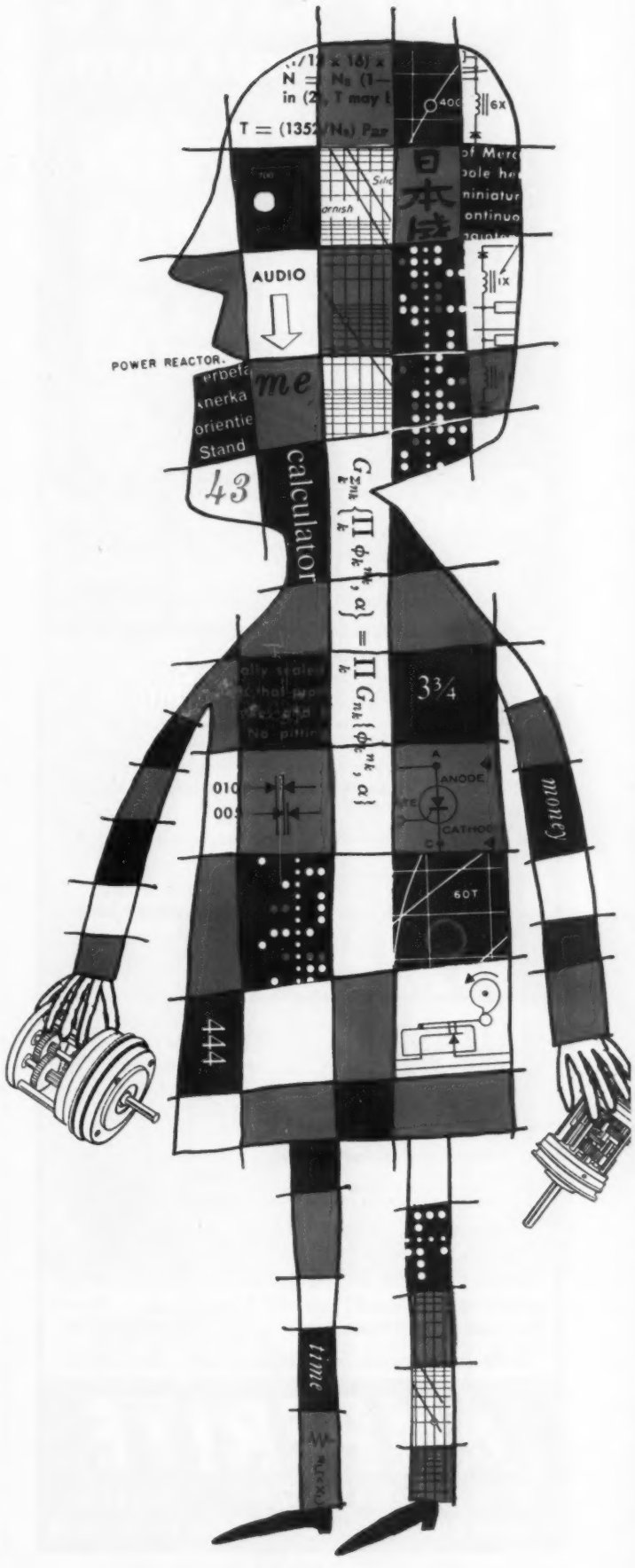
Thus far this discussion has been rather general and in some ways is epitomized by the following story: A missionary who was captured by cannibals was placed in the pot to be prepared for dinner. On looking over the top of the pot, he was surprised to see the cannibal chef sitting against a tree and reading a book entitled "A Thousand and One Ways to Serve Mankind". We expect that there will be little objection to the general thesis that more attention should be paid to people and their needs, but the problem becomes one of choosing a program to meet these needs from among a wide variety of possible approaches.

PSYCHOLOGISTS IN INDUSTRY

Before discussing those areas served by psychologists working in, or as consultants to, industry, perhaps it would be well to define a psychologist. A psycholgist, even though he may later function as a practitioner, is trained as a scientist and earns a Ph.D. degree. Although he frequently learns much about mathematics, physics, and physiology, he is basically a behavorial scientist trained in human behavior and interpersonal relations. Psychologists do not read minds or see through people or have magical answers to the problems of living. They do endeavor to systematically apply the insights of psychological science to a variety of problems.

When the problem is one of human engineering, of fitting the machine to man (or man to the machine), scientific method can be applied in a rather straightforward manner. However, when the problem involves communication among executives, employee morale, promotion practices or other

The authors are both basically clinical psychologists holding Ph.D. degrees in this field. They also hold post-doctoral master's degrees in public health practice and administration. They have administered large scale, multi-faceted programs, and have served as consultants to private and governmental organizations. Both have published extensively, and are particularly interested in administrative evaluation, and in the identification and maximal utilization of human abilities within organizational settings.



issues with interpersonal features, the scientific approach must be tempered with clinical sensitivity heightened by years of experience and training as a participant observer in diadic and group interpersonal situations. As one author states it, he learns to "listen with the third ear". Another way of putting it would be to compare him to the experienced pilot who senses a dysrhythmia in his engines before anyone else and even before the instruments detect it. Trained, skilled, sensitive people are still the best means for diagnosing and helping to resolve human problems.

Psychologists with training in industrial methods, as well as those with specialization in clinical, counseling, and consulting techniques can all be found in various roles in industry. All qualified psychologists are members of the American Psychological Association, which publishes an annual directory listing the training and experience of its members. In addition, most states have state psychological associations, and an increasing number of states are requiring certification or licensure of anyone using the title "psychologist." Psychologists can also obtain a Diplomate in the specialized areas of Clinical, Counseling or Industrial Psychology after five years of post-doctoral experience and a series of rigorous examinations. Information about psychologists can be obtained by writing to the American Psychological Association, Inc., 1333 Sixteenth Street, N.W., Washington 6, D. C.

To return to the question of some of the approaches by which the psychologist may serve industry, we shall choose to mention four general areas: selection and testing, management development, counseling and consultation, and employee motivation. We shall take up the first of these topics below and expect to treat the others in more detail in subsequent articles. Such problem areas as recruiting, training and maximizing the effectiveness of the individual and the group, as well as methods for identification, consultation, and counseling individuals whose output may be negatively affected by transient personal stress will also be discussed at a later date.

SELECTION AND TESTING

Selection and testing are perhaps the most widely known functions of the psychologist and are frequently, albeit

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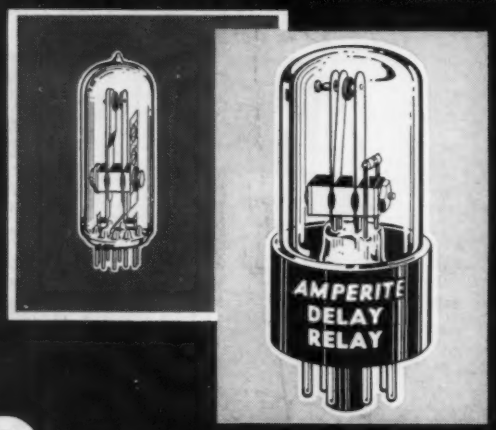

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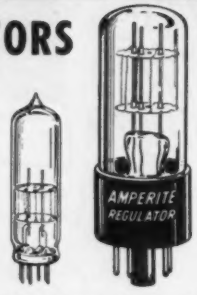

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erroneously, considered to be his only functions. Recent years have seen much progress in improving the reliability, validity and sensitivity of tests. We now have measures for aptitudes, attitudes, intelligence, personality, achievement, manual dexterity, interests, values, imagination, etc. Testing procedures range from mass screening through so-called group administered "paper and pencil tests" to several days of comprehensive individual assessments. The former would probably be used for hiring assembly line workers or clerical personnel, and the latter would be used in assessing the more complex requirements for executive positions.

It should be pointed out that psychologists are fully aware of the folklore that has arisen around testing procedures and of how anxious most individuals are made by the testing situation. The ethical psychologist derives no pleasure from the discomfort of fellow human beings, and except for those instances when the situation requires an estimate of ability to tolerate stress, will make every effort to make the experience as pleasant a one as possible. In fact, many professional and technical people while being tested, have taken a scientific interest in observing and trying to understand the methods and instruments of another discipline such as psychology. A good number report that they have enjoyed and been stimulated by this experience.

There are many standardized tests for various purposes which are commercially available. In general, these tests can be divided into four major categories: intelligence, achievement, aptitude, and personality.

Intelligence tests (often called tests of "mental alertness" in industry) vary from short, quick self-administered tests, such as the Otis Mental Ability Tests, to such individually administered lengthier tests as the Wechsler Adult Intelligence Scale. If you need a rapid, fairly reliable test, requiring only 20-30 minutes to take and to be administered to a large group of personnel for a screening device, you would use the Otis. On the other hand, the Wechsler test takes more than an hour to administer, can only be given individually, and requires careful training in the interpretation of both qualitative and quantitative features. For example, it might be used in evaluating and differentiating among members of a group of managerial personnel who are being selected for a special intensive and expensive training program.

Achievement testing or, as it is often known in industry, "proficiency testing" or "trade testing" is used to measure the degree of skill an applicant may have for a position in relation to other applicants or employees. Thus, these tests measure previously acquired training or knowledge. For example, these tests may vary from measures of stenographic skill, such as the Seashore-Bennett Stenographic Proficiency Tests, to such tests as the Purdue Test for Electricians or the Minnesota Engineering Analogies Test.

Aptitude testing is used in industry when inexperienced workers are to be selected and trained in a future skill. They are measures of present ability which could be related to the future requirements or skills. For example, such a test as the Purdue Mechanical Adaptability Test is used to measure an individual's future ability to learn operations in the mechanical and electrical field. Skills for clerical positions may also be measured by aptitude tests as well as the manual dexterity necessary for machine workers or small assembly work.

The last group of tests are those which measure personality traits. This area of selection and evaluation is still in its infancy, but is gaining in interest and being further developed each year. Industry is becoming increasingly con-

cerned in preventing and reducing problems caused by maladjusted personnel, cutting down personnel "wastage" due to personality difficulties, and enhancing personnel who show personality characteristics for a high level of job success. These tests can be so-called pencil and paper personality inventories which are self-administered or complex projective tests, which are relatively unstructured situations in which an individual can project his personality attributes by the way he responds. Some of the group tests can be used as screening devices, such as the Guilford-Martin Personnel Inventory, which is used to spot potential personality problems. On the other hand, such tests as the Rorschach or the Thematic Apperception Test, which are projective techniques, are generally administered on an individual basis, require a lengthy period for analysis and afford many important clues regarding the emotional, intellectual and personality features of the person being assessed.

ADMINISTRATION OF SELECTION PROGRAMS

Tests are frequently employed en masse with more or less success by regular company staff members, particularly by the personnel department. However, the proper administration of a well-rounded and scientifically grounded selection program requires the services of trained psychologists, whether these be from within the company or hired on a consultant basis. There are many reasons for this. Test results must be carefully interpreted; the correct test battery must be employed; there may be a need to develop a careful combination of tests and other techniques such as interviews; fairly complex statistical methods may have to be employed; specific standards must be developed for the use of particular tests in different settings, etc. Such services can be adequately provided only by the qualified, trained, and experienced psychologist. In general, most major-sized firms that develop a large-scale selection program utilizing tests should add a full-time psychologist to their personnel staff. For smaller concerns, a psychological consulting firm might be used, or a member of the personnel staff might be sent to a university for long-term, intensive, specialized training in psychology.

When a firm utilizes a professional psychologist, he may prefer to create a special battery to meet the particular needs of the company. Although this may be more expensive at the start, it will in the long run provide more valid selection procedures. This implies the development of *a criterion measure for personnel in a particular firm*, against which the selection tests can be validated. There are a wide variety of criterion measures ranging from such concrete measures as "output" on a production line to "level of responsibility" for middle management personnel. The psychologist or other personnel who employ tests must also be aware of three other major factors: the validity, reliability and norms of the selection devices they employ. Unless the characteristics of the tests are established in relation to these three elements, and the results reported in the psychological literature, we do not have a psychological test but only a series of questions.

The most important factor is *validity*. This implies that the test measures what it purports to measure. The best way to establish a test's validity is to compare the results with job performance to see if the test can differentiate between personnel in regard to success of the job. As the job becomes less concrete and more abstract, i.e., management decision making ability, this becomes difficult to measure. The second factor is *reliability*. The basic question is: "Does the test give similar results upon retesting?" Although tests can be reliable, this does not mean that they are necessarily valid. The third characteristic is *norms*. For a test to be meaningful, there should be specific information about the sample of persons with whom the test was tried

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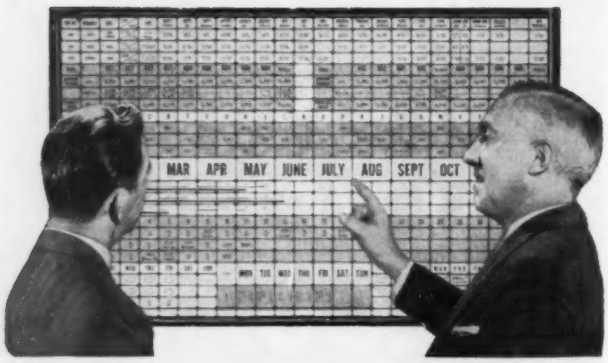

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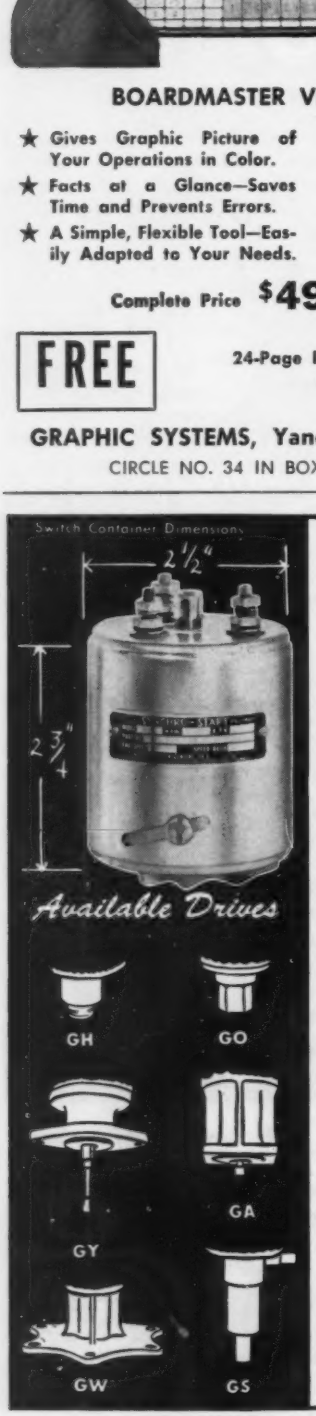

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out and developed, as well as the statistical methods for obtaining the test scores.

SELECTION FOR EXECUTIVE POSITIONS

As mentioned earlier, selection for executive positions might require extensive and intensive assessment procedures. These procedures are not merely tests, but would include special interviewing as well as evaluations of the man's current and past job functioning. Newer and better methods for accurately appraising an individual's work performance have been developed. The tests can be useful in highlighting personality characteristics needed for the job under consideration. These procedures may become especially necessary for promotional advancement from among executives currently employed in positions that have not allowed for or required the display of characteristics that may be important for the new job.

Aside from the individual job to be filled, there are some general areas in which psychological appraisal can be useful. The simplest of these might be merely to confirm management's own judgment and selection of a man. Merely by removing any lingering doubts or by strengthening their certainty, the psychologist has rendered a valuable service. A company planning to merge with or buy another company may want a consultant to evaluate the managerial staff before making a final decision. Still another useful service would be in providing a catalog of management skills so that if and when the company expanded, it would know what resources could be tapped from within.

A firm that is going to initiate a testing program would be well advised not to start it under great pressure as, for instance, when a vice presidency is to be filled. Beginning to plan well ahead of need during a period of calm when the other executives are not keyed up vying for the position promises a much sounder program with much less possibility of error.

The reduction of the possibility of error or, conversely, the increase in the probability of successful selection should be the terms in which a company thinks of a testing program. Testing is not perfect, and many intangibles can only be approximated in terms of tests. In addition, and especially at the executive level, management's own judgments are vital considerations to which the psychologists' findings are useful adjuncts. It is much easier for tests to predict successful assembly line performance than it is to predict executive success, but then it is easier to describe exactly what a production worker does than what a company officer does. The complexity of managerial problem analysis, sifting for implicit factors, organizing facts, and decision making is extremely difficult to measure. On the positive side is the fact that even with their limitations, psychological tests and methods have real value. They can highlight the strengths and weaknesses of personnel so that guidance toward the right job and/or counseling to overcome some of his limitations may be provided for the individual.

A good set of rules to keep in mind as suggested by P. W. Boynton in *"Selecting the New Employee,"* New York: Harper & Bros., 1949, p. 109, is as follows:

"1. No single test has ever been devised which is adequate in itself to determine whether or not an applicant will be the kind of employee you want.

2. No test is useful unless you know first what information you are seeking.

3. No test is significant unless it is administered by a

competent trained specialist in the field who knows how to give it and how to appraise the result.

4. No test is valid unless it tests the qualities it is supposed to test.

5. No test is practical unless it has been scientifically designed to fill your own specific needs.

6. No test can supplant the interview. It serves only as a supplementary aid."

SELECTING R & D PERSONNEL

Everyone in the research and development field as well as the intelligent reader of the daily newspapers knows of the keen competition and acute demand for R and D personnel. The rapid turnover in many positions is common and costly. Again, a certain amount of turnover as especially able men reach for new opportunities or as companies release other men who do not work out is to be expected. What is wasteful is when a company loses an able man because management did not know enough about him or their own structure to keep him growing for them.

There have been some very promising new developments in the area of selecting R and D personnel. These involve the company's looking very carefully in detail into the particular job, job environment, supervisor, and associates with whom the new man will be placed. Conversely, the applicants are studied not merely for their technical competence, but for the kinds of situations in which they will work best and under what kinds of supervision. It is then possible to match the applicants to the needs of the particular job opening so that, for example, a very creative man is not put into a routine job with which he will quickly grow bored or a good routine man is not required to be more creative than he is. This approach also includes a method of following the successful applicant into the job and evaluating his performance on a continuing basis. Thus, if after a period of successful performance there is a drop in proficiency, management is alerted to look into the situation which may require employee counseling, consultation with his supervisor, or perhaps promotion to a new level of responsibility.

We have discussed how psychological services can aid management in selecting the best possible candidates for employment. These employees become the human resources of the company without whom there will be no products. In subsequent articles we will discuss ways of nurturing and conserving these resources, of helping personnel to develop their potential and increase their productivity. The rewards are not merely those which accrue to the company, but there is the additional very real value of enhancing the self-actualization of the individual.

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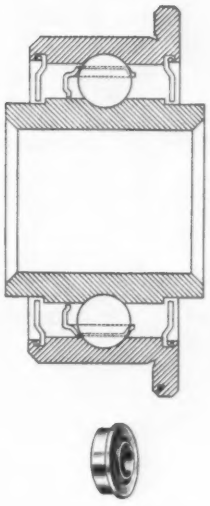

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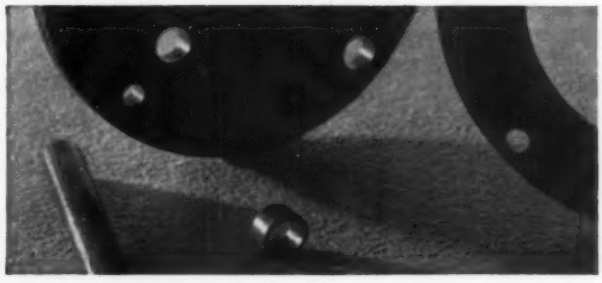

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TECHNIQUES

THERMAL PROTECTION FOR AIRBORNE ELECTRONIC SYSTEMS

Robert H. Sando, *Westinghouse Electric Corp., Baltimore, Md.*

The thermal environment for airborne electronic equipment is contributed by the natural condition of the atmosphere and the induced effects from aerodynamic heating, electronic equipment heat, and power plant heat. Unfortunately, most electronic equipment, whether heat-generating or nonheat-generating, is sensitive at some level of temperature. Some form of thermal protection is required to keep component temperatures low enough for satisfactory performance over the desired operating period.

Electronic system designers have three approaches for providing thermal protection: decrease the heat loss from the equipment; develop components suitable for higher operating temperatures; and provide efficient means for heat removal.

EQUIPMENT HEAT LOAD

Growing heat load of airborne electronic equipment can be demonstrated by the increase in heat dissipation of typical Westinghouse radar systems shown in Fig 1. The increase is largely due to greater range requirements of modern radar systems. A high percentage of input electrical power, 85 to 90 percent, is transferred into heat.

The most direct approach to thermal protection is to use electrical components that generate a minimum amount of heat. For example, using transistors in place of electron tubes will reduce heat load. If subminiature tubes in a typical circuit are replaced by transistors, the heat load can be reduced by a factor of 50 to 1. However, this move doesn't necessarily simplify the problem because transistors are more sensitive to high temperature than tubes. Conventional design techniques permit subminiature tubes to operate in an ambient environment of 175 C, whereas, germanium transistors are limited to 55 C and silicon transistors to 100 C.

Another complication is created by miniaturization. Although miniaturizing a piece of equipment may decrease the heat load it may at the same time increase the heat density (watts per square inch of surface area). This condition can result in failure of the natural modes of heat transfer to maintain satisfactory steady-state temperature.

HIGHER OPERATING TEMPERATURES

Electronic equipment should be designed to minimize destructive effects of temperature extremes by attacking combined electrical and thermal problems during preliminary equipment design.

Structural materials, such as aluminum and steel, lose strength with increased temperature. Decrease in strength at elevated temperatures for several structural materials is shown in Fig 2. The designer must keep temperature effects in mind when choosing a specific structural material and type of structural design.

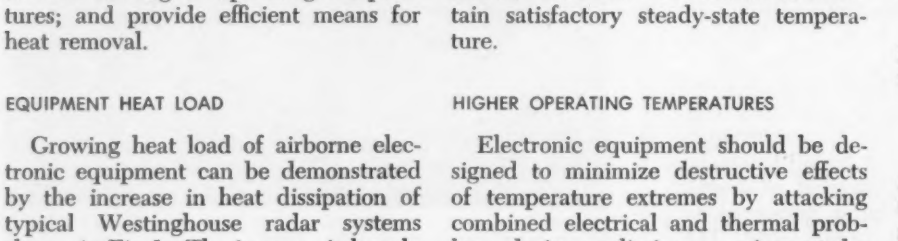


Fig 1 Growth in heat dissipation of typical airborne radar systems.

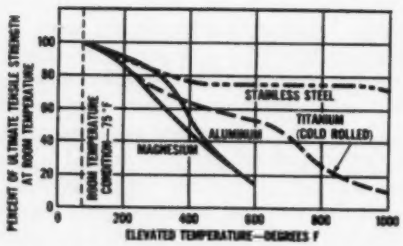


Fig 2 Structural strength of these typical materials is a function of temperature.

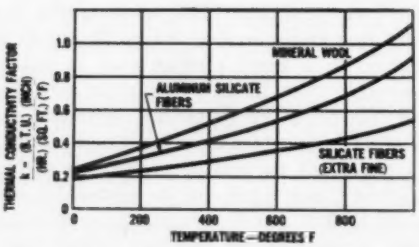


Fig 3 Conductivity of typical insulation materials changes with temperature.

Temperature also affects both the magnetic and non-magnetic characteristics of "electrical" materials. The insulating property of material decreases as the temperature increases. This change in conductivity with temperature is shown in Fig 3.

Some protection can be provided for temperature-sensitive equipment by separating heat-generating and nonheat-generating components, either by different physical location, or individual equipment insulation.

For equipment with a short operating period, such as in missiles, thermal lag principles can often be employed effectively. Use of materials with low thermal conductivity, low density, and high specific heat can offset the effects of aerodynamic heating during high-speed flight.

For example, assume 10 pounds of material has a maximum allowable temperature rise of 100 F, and the heat input to the material is 75 Btu per

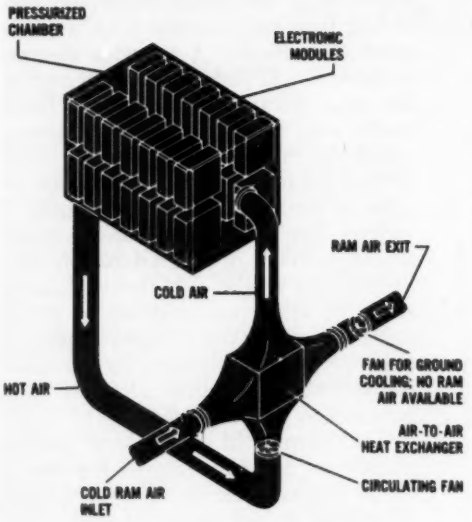


Fig 4 Ram air pressurized cooling system.

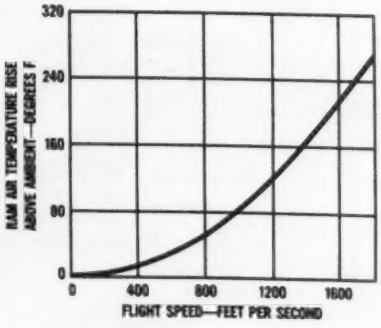


Fig 5 Ram air temperature is proportional to the square of aircraft velocity.

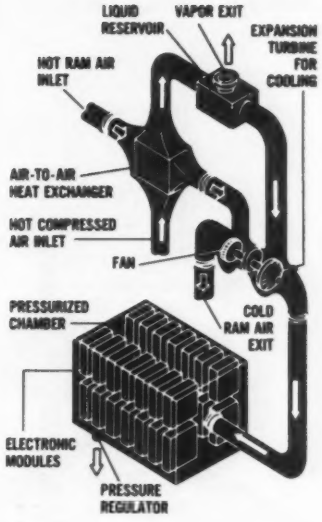


Fig 6 Air cycle pressurized cooling system.

minute. If the material were copper, the thermal lag period would be 1.23 minutes, whereas beryllium would have a thermal lag period of 6.14 minutes.

Thermal insulation of compartments housing electronic equipment can further decrease the rate of temperature rise of ambient air inside the compartment.

REMOVING HEAT LOAD

Where available techniques and materials for reducing heat load and increasing critical operating temperatures are not sufficient for thermal protection, heat must be removed from the equipment.

Air-to-Air – One of the simplest and most reliable methods of heat removal is the ram-air pressurized system, (Fig 4) using an air-to-air heat exchanger. If dielectric breakdown is a problem, a gas such as sulfur hexafluoride can be used in place of air in the pressurized cooling loop.

If the electronic equipment compartment does not need to be pressurized, ram air can be ducted directly into the compartment, eliminating the heat exchanger.

The major disadvantage of this system is the working temperature of the ram air. Excessive speeds produce adiabatic compression of the ram air. The temperature of ram air is a function of the square of aircraft velocity, as shown graphically in Fig 5.

Air-Cycle Cooling – If inlet ram air temperature approaches the critical component operating temperature, a more complicated cooling cycle is required. One possibility is the air-cycle pressurized system, shown in Fig 6.

Cooling air is provided by a high-pressure source – in this case, from a stage of the main aircraft jet engine compressor. The high-pressure air is first cooled and its pressure is slightly reduced by passing it through an air-to-air heat exchanger. The air next flows through an expansion turbine, where temperature and pressure are reduced to the values needed for cooling.

The turbine shaft horsepower developed during the expansion process is absorbed by a fan, located in the exit duct of the ram air flow. This fan also increases the flow rate of ram air through the heat exchanger.

An auxiliary blower must be provided for cooling during ground operation of electronic equipment.

Liquid Cooling – In some cases, a liquid–such as water or water-ethylene glycol–provides the most efficient method of heat removal. Since the heat absorption capacity of a substance is directly proportional to its specific heat, four times as much air as water (by weight) is required for equal cooling performance.

With liquid cooling, each heat-generating component or assembly is connected to heat-conducting rods, which are immersed in the cooling liquid by a liquid-to-air heat exchanger (Fig 7).

Another method of applying this system is to fasten the liquid pipes directly to the bottom of each chassis supporting heat-generating components. Complete or partial immersion of equipment in liquid is another method sometimes employed.

Evaporative Cooling – An expendable evaporative cooling system possesses a high degree of reliability. Heat is removed by the simple process of vaporizing a liquid at its boiling point. Obviously, the boiling point of the liquid must be below the critical operating temperature of the electrical components. Boiling point of the liquid can be controlled by the pressure to which it is subjected. Other factors, such as latent heat of vaporization, density, and freezing point are considered in selecting a suitable liquid.

Use of this cooling method is limited by the operating period; weight of the liquid required for long time periods may make the system undesirable. Evaporative cooling is readily adapted to missiles, where flight time is short.

One type of expendable evaporative system is shown in Fig 8. Ammonia under pressure is passed through an expansion valve, and the resulting cooling ammonia gas passed through a heat

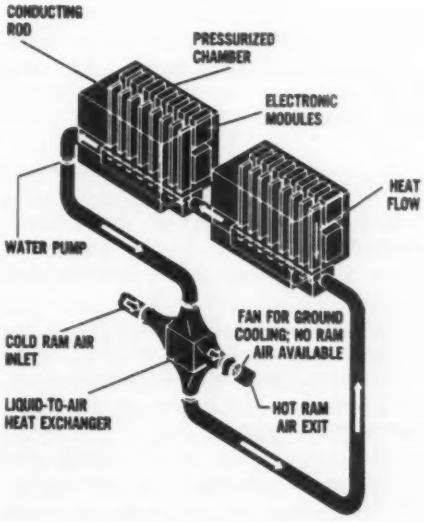


Fig 7 Liquid cooling system.

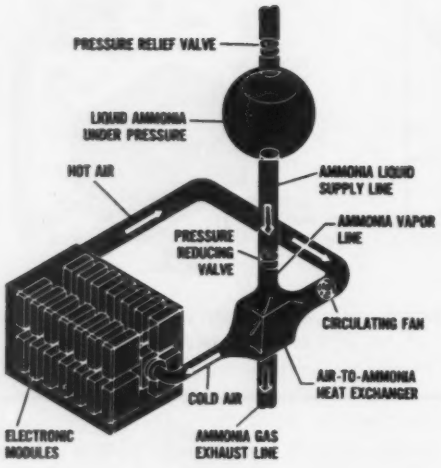


Fig 8 Expendable evaporative cooling system.

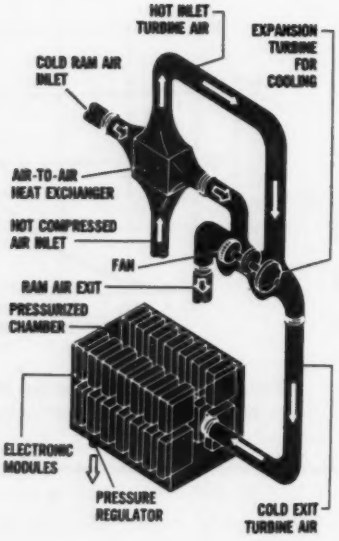


Fig 9 This system employs the combined cooling effects of ram air, bleed air, evaporative cooling, and an expansion turbine.

exchanger and exhausted overboard. Other suitable liquids are water, water-ethylene glycol, and freon solutions.

Evaporative and Air Cycle – An expendable evaporative system can be used as an intermediate cooling step in the air-cycle system, as shown in Fig 9. This system uses the combined cooling effects of bleed air (compressed air), ram air, evaporative cooling, and an expansion turbine.

Operation of this system is similar to that shown in Fig 6 except that the evaporative cooler removes heat before the air is passed through the expansion turbine. Hence, in this system, the boiling point of the liquid solution can be higher than the operating temperature of the electrical components. This combined system is capable of controlling high heat loads.

COOLING RADAR SYSTEMS

In the application of these basic methods to actual design problems, many combinations of the basic modes of heat transfer can result.

A typical application example is an airborne radar system. In the radar transmitter, the major heat-generating components are the power supply, modulator, and klystron tube. The component parts of the power supply are sealed in a compartment containing sulfur hexafluoride gas under pressure to prevent dielectric breakdown. The gas is circulated through the compartment and passed through a gas-to-air heat exchanger, such as shown in Fig 4.

Components comprising the modulator are sealed in a compartment with air at a pressure slightly higher than sea level. Compartment air is circulated through an air-to-air heat exchanger.

The klystron tube is designed for liquid cooling. Heat is transferred from the tube parts to the liquid, which is passed through an air-to-liquid heat exchanger, such as shown in Fig 7.

Component parts of the receiver are cooled by passing ram air directly over the heat-generating parts. Hence, this typical radar system is cooled by a combination of four cooling methods.

PHOTO-ELECTRIC TRANSDUCERS

Stability of Photo Pickoff Meets Requirements of Missile Instrumentation

Photo-electric force and motion transducers have not had wide acceptance in the missile field, due to a long term stability problem and the large displacement required of a sensor. In seeking answers to these problems, White Avionics Corp., Plainview, L. I., N.Y., has applied new materials and improved circuit designs.

Control of the light source over long periods of time was accomplished by maintaining a tungsten element light source at a low temperature and providing feed-back control from a photo conductive diode. A tungsten element at 2400 F will yield a peak intensity in the near infrared region and a photo diode can be selected for maximum sensitivity in the same region. New N-type photo diodes where a P-type region is established around a point of contact has provided an improvement in the problem of re-combination rate. Such photo diodes are also sufficiently small to allow miniaturization in the design of a pickoff. Improvement in circuitry and components for the associated amplifier further allow for miniaturization and high reliability.

The output of the photo pickoff transducer can be designed for use in either digital or analog control systems depending on the sensor. A digital system requires a sensing mechanism capable of yielding a change in frequency proportional to the change in input of the phenomenon to be measured. With sufficient displacement of the sensor, for interrupting the light path between the control source and the photo diode, a pulse output can be obtained as a function of the input.

An analog system requires a sensor for measuring phenomena whose displacement is proportional to the input. By utilizing this displacement to interpose a shutter in the light path between the controlled source and a photo diode, an output is obtained whose amplitude is a function of the input.

The photo pickoff devices are presently in the development stage, and while the temperature range is limited by the semi-conductor materials, White Avionics has been encouraged to further pursue development work.

Write No. 171 in Box on Inquiry Card

Precious Metal Brazing

Slotted along it widest dimension, a brazing alloy strip, called Wesgo Polyform can be bent around virtually any contour, thereby forming round, rectangular, oval or any other shape desired. Principal economic advantage claimed for the new form over conventional punched washers is the elimination of scrap which is particularly beneficial in precious metal alloys. Eliminated is the necessity for special tooling to produce unconventional shapes. Available in all of the low vapor pressure brazing alloys, the Polyform strip can be supplied in thicknesses down to 0.002". The width of the serrated or punched out section can vary from ⅛ to ⅜" in 1/64" increments. Western Gold & Platinum Co., Belmont, Calif.

Write No. 700 in Box on Inquiry Card

DIE-STAMPED CIRCUIT BOARDS

High Level of Uniformity and Reliability at Low Cost

Circuit boards are made by die cutting the conductor pattern from metal foil coated on one side with a thermo-responsive adhesive and simultaneously bonding the circuit to the insulating base material under heat and pressure. Use of long-wearing embossing dies permits production runs of approximately four million circuit boards without die change while maintaining tight tolerances on the circuit.

Thoroughly field tested, the die-stamped boards are now being mass-produced by Dytronics, Inc., Rochester, Mich. for a wide variety of automotive, appliance and control applications and are gaining acceptance for use in instruments, computers, etc.

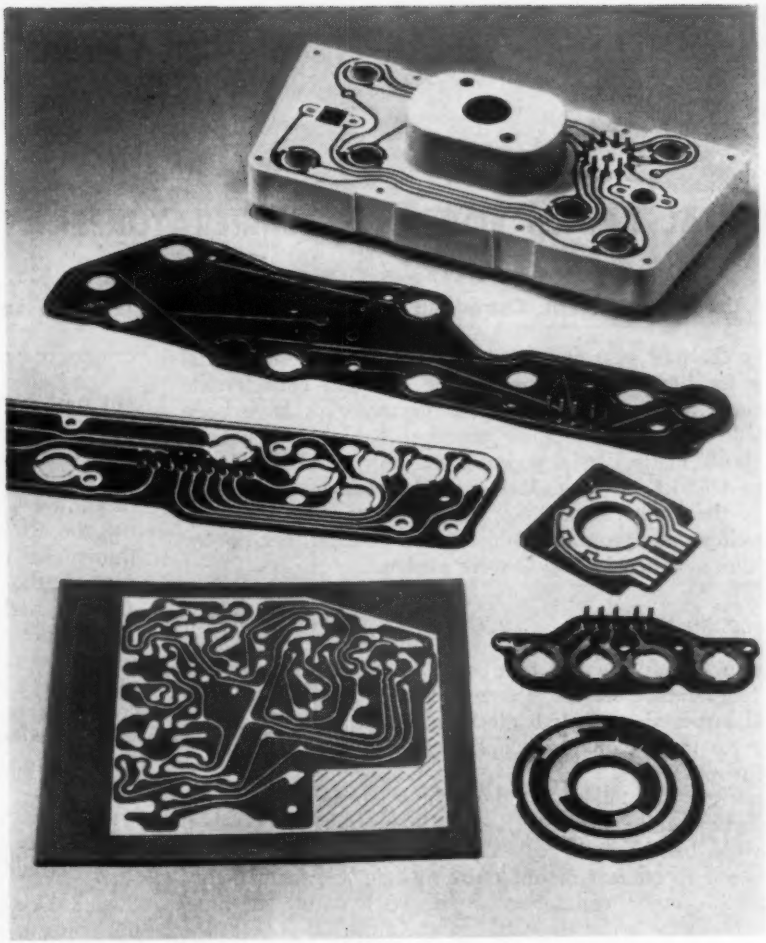
The company reports that the die stamped circuits have provided savings of 10 to 40 percent over etched circuits. The principal manufacturing cost is that of making the die, hence the larger the quantity required of an identical board the greater the saving. In general, the company explained, an order for 25,000 or more circuit boards can be produced at less cost by die stamping than by etching.

Since the die stamped circuits are produced by a dry process, with no excess metal to remove by chemical etching, the base material is not degraded by moisture and etchants, nor is there any hygroscopic adhesive residue remaining from the excess metal. Thus the base retains its high insulating properties and no high order of consideration need be given to chemical resistance when selecting a base material.

In addition to the usual laminated plastics, vulcanized fibre and thermo-setting and thermo-plastic molded materials can be used as a base. Any metal to which adhesive can be applied may be used for the conductor, although copper is almost always specified. Other available conductor metals include aluminum, brass, silver, gold, Nichrome, phosphor, bronze, plated metals and steel alloys.

Die cutting the metal produces a highly uniform circuit configuration with exact line definition. The conductor lines are sharp and clean, with no cracking, undercutting or residual copper problems. Moreover, the embossing action tucks down both edges of the metal conductor into the base material, increasing the bond and producing reliable edges.

The same pilot holes are used for piercing and blanking operations on the circuit board as for the die stamping cycle which produces the conductor pattern. This assures extremely accurate registration between the conductor pattern and all piercings. Tolerances can be held as tight as 0.003 inch.



These die stamped circuits are typical of the wide variety made by Dytronics, Incorporated, Rochester, Michigan, a subsidiary of Taylor Fibre Co. Die stamping process is an economical method of mass producing circuit boards at a high level of uniformity and reliability.

The die cutting method of producing the circuit also makes it practical to specify thicker conductors to carry heavier currents. For example, conductors up to 0.015 inch thick may be used and die stamped circuits may be designed to carry more than 40 amps.

Bond strength between conductor and base material can be consistently maintained at 10 pounds minimum per inch of width—as translated from 1/16 inch wide conductor. The NEMA standard bond strength for etched circuits is 6 pounds minimum per inch of width.

The same conductor patterns can be produced in Dytronics die stamped boards as in print and etched circuits, although minor changes are sometimes required to facilitate mechanical production. Of principal importance are the line widths and spaces between the lines. In both cases this should be held to 0.06 inch minimum—narrower line widths and spacing increase circuit costs and decrease circuit reliability. Sharp corners and connection points should be avoided by designing fillet radii at these points. An ideal radius is 0.12 inch.

Dytronics die stamped circuits can be supplied with immersion silver flash, electrosolder or electrosilver platings and with finishes of epoxy resins, silicone resins, acryllic spray, waterdip lacquer and screened lacquer.

Write No. 153 in Box on Inquiry Card

Relay and Capacitor Kit

Designed especially for prototype, development and engineering labs, a kit consists of 20 standard micro-miniature relays (Mil-R-575 and Mil-C-25018) in three header and four mouuting configurations; 150 hi-temp ceramic capacitors (Mil-C-11015) from 39 uuf to 10,000 uuf; and a compacy container complete with engineering data drawer. The price of the relays and capacitors is said to provide a saving of 30% over normally small prototype quantities. Telecomputing Corp., Van Nuys, Calif.

Write No. 701 in Box on Inquiry Card

COAXIAL CABLES FOR HIGH TEMPERATURES

Semi-Air Space Design Combined with Proper Materials Provide Long Life Operations at 300 and 500 C.

During the past year or so the problem of designing coaxial cables for high temperature service has had considerable attention. Several potentially suitable materials have been available and a number of practical cable constructions have been made. In a paper presented at AIEE Northeastern District Meeting, Messrs. A. L. McKean and S. W. Trill of the Phelps Dodge Copped Products Corp. describe a development program from which coaxial cables for operation at 300 and 500 C were evolved.

BASIC DESIGN APPROACH

Selection of a particular type of coaxial cable design for high temperature service was based upon consideration of several aspects; potential electrical performance, adaptability to possible materials, physical stability, and subsequent manufacture.

Engineers at Phelps Dodge chose a semi-air space construction, called Spirafil, because it provided the lowest loss, wide band coaxial cable performance known and it lends itself to effcient manufacture in long lengths. In this design the inner conductor is suported within a tube outer conductor by a dielectric in the form of a helically applied thread.

CONDUCTOR DESIGN

On past performance, copper, with its known satisfactory electrical and physical characteristics, was a natural first choice but protection was necessary to prevent progressive oxidation and corrosion at high temperatures. Silver and nickel were satisfactory for this purpose, and the former has the attraction of providing excellent conductivity. The thin nickel coating under the silver acts as a barrier, preventing the formation of a high resistance copper-silver alloy at high temperatures.

A marked advantage was gained from the 1000 F/60 F resistance ratio of the silver-nickel combination as compared to 2.5 for silver and 10.0 for nickel. While this combination could be applied to the inner conductor, it was not immediately available for the inner surface of the outer conductor; plating methods being limited to short lengths.

TUBE DEVELOPMENT

Phelps Dodge engineers investigated several methods of providing a silver-on-nickel inner surface. Techniques included the plating of comparatively large tubes by various process variations, followed by drawing, but development in another direction culminated in a successful method. In this approach, a laminate of the metals in suitable proportional thicknesses was fabricated and shaped from a flat circular section into a thick walled tube and then drawn down to the diameter and wall thickness required. The result was a uniform thickness of metals with the physical structure of the silver made tougher by the drawing process.

Fig. 1 Spirafil 300

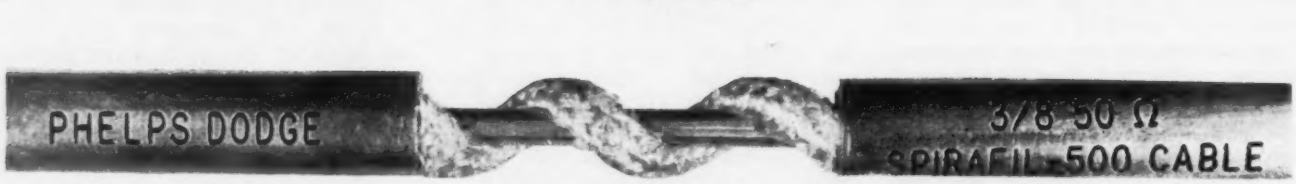


Fig. 2 Spirafil 500

Components Digest #10, "Materials & Techniques For High Temperature Components," in the December 1959 issue of ELECTROMECHANICAL DESIGN, covered the problems involved in designing electromechanical components for high temperature environments. From time to time, we shall present techniques employed by individual companies in the designing of various electromechanical units for high temperature performance.

If you or your company have recently come up with answers to design problems in this area, drop us a note and we'll help you call it to the attention of our readers.

DEVELOPMENT OF DIELECTRIC

In selecting the dielectric as a helical filament insulation, specific requirements included the following characteristics:

- Low power factor over the temperature range.
- Low dielectric constant over the temperature range.
- Thermal stability.

TEMP. RATING IN °C	CHAR. IMP.	VEL. %	DIEL. K	CAP. MMF-FT.	DIELECTRIC STRENGTH-VOLTS	POWER RATING WATTS-1000 MC PER 100°C RISE	DIEL.
300	50 Ω	93	1.16	22	2300	400	TEFLON
300	50 Ω	93	1.16	22	2300	400	TEFLON-F (filled)
500	50 Ω	80	1.55	26	3700	700	REFRASIL
500	50 Ω	80	1.65	26	3700	700	QUARTZ

Fig. 4 Electrical Characteristics of Phelps Dodge's 300 and 500C Cables

- Flexibility.
- Adequate strength for application as a helix.

General stability under high temperature service conditions, either continuous or cyclic, was considered most essential.

DIELECTRIC FOR 300 C

Teflon was the only organic material considered for this service. Engineers found that its tensile strength falls off sharply close to its critical transition temperature of 327 C but it was satisfactory at 300 C and tests have shown that it has an efficient short term RF life even at 500 C.

Investigating the use of fillers in Teflon, engineers at Phelps Dodge came up with a filament containing 15% mica which provided improved mechanical stability as a result of the reduction in the co-efficient of expansion. Fig. 3 gives a comparison of the co-efficients for Teflon and filled Teflon (15% mica) at temperatures from −65 to 300 C.

DIELECTRIC FOR 500 C

Use of inorganic materials of the silica or ceramic group were considered; for example, Refrasil, Fiberfrax, Cabosil, Eccofoam, Pyroceram and quartz. Stringent requirements segregated two of the materials for continued evaluation and development; Refrasil and quartz fiber.

Refrasil is a vitreaus silica now available with a pure silica content of 99% plus. The friable nature of the material demanded the use of a lubricant to permit manipulation. Investigation was directed towards eliminating or replacing the lubricant and modifying the processing or treatment of Refrasil to obtain the best power factor and dielectric constant. It was observed in initial testing that the normal power factor was not as low as should be expected and was unstable over a temperature range. This was associated with a affinity for moisture and an apparent hydrolised state. From a series of samples a condition for treatment was established that reduced considerably the susceptibility of Refrasil to collect moisure. The next step was to replace the normal lubricant, which left undesirable residues adversely effecting electrical characteristics, with a Teflon dispersion. Again from a sample series, a treatment for removing the dispersion vehicle was determined and an optimum power factor of 0.001 was reached.

Quartz fiber is also a vitreous silica but with a purity of 99.7% plus. Again a lubricant was necessary to enable handling and fabrication and again the lubricant had to be removed by heat treatment at an appropriate stage in cable manufacture. Time/temperature treatments were investigated to develop the best dielectric performance. A power factor of the order of 0.0007 was achieved.

TEMPERATURE		TEFLON	FILLED TEFLON (15 % MICA)
°F	°C	10^{-5} IN./IN./°C	10^{-5} IN./IN./°C
−85	−65	5	3
+75	+24	6.5	5.5
+450	+232	14.5	10
+570	+299	33	16 − 20

Fig. 3 Coefficients of Expansion

FUTURE DEVELOPMENTS

To extend the range of operating environments, future developments in cable design may involve the following considerations:

- The dielectrics presently employed can be considered for higher temperatures.
- Inner and outer conductors could be formed from alloys capable of withstanding higher temperatures, with silver as the conducting surface.
- Extension of range of cable sizes is considered practicable up to approximately ⅞" O.D.
- New advances in the technology of synthesizing materials have become an every day occurrence; it is possible within two years new dielectric materials may be available for performance in very high temperatures.

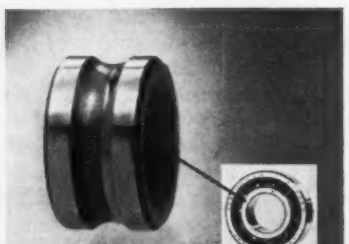
Write No. 151 in Box on Inquiry Card

A NEW PRODUCT DEVELOPMENT FROM BARDEN

PERFORMING WELL IN A HOT SPOT

As every parent knows, small boys have an amazing capacity to perform well in heat that would fell the average adult. In much the same way, BarTemp* ball bearings operate effectively up to 575° F., permitting synchros, fans, control motors and other lightly loaded devices to perform at higher temperatures than ever before.

*TRADE MARK



▲ Unretouched photo of inner ring from BarTemp bearing that ran 2727 hours—1010 hours at 500°F. plus an additional 1717 hours at 575°F. Dark band in raceway is lubricant transferred from retainer.
▼ Excerpts from lab and field test results.

Bearing	Temperature	Speed (RPM)	Hours
SR3HX110	500°F. 575°F.	1,200	2727
SR4HX110	338°F.	10,000	2500+
SR3HX110	392°F.	1,200	1240+
SR3BSSX112	500°F.	4,500	1036+
SR2HX110	575°F.	2,500	1628

NEW DESIGN DEVELOPMENTS

Two design innovations made BarTemp possible—a Barden-developed heat treatment for stainless steel used for the bearing rings, and a new retainer that serves as a dry lubricant and a ball separator. The BarTemp retainer, reinforced Teflon compounded with a solid lubricant, is the sole lubrication required. As the bearing rotates, the balls transfer microscopic particles of the lubricant to the raceways.

TEST RESULTS

In tests by more than 20 precision bearing users, BarTemp bearings in synchros, control motors, blowers, pressure switches, tachometer generators and other lightly loaded devices have operated from 1000 to 24,000 RPM and at temperatures from —100°F. to 575°F. Typical life exceeds 1,000 hours.

PROTOTYPES AVAILABLE

Prototype quantities of seven BarTemp sizes from .3125" to .7874" O.D. are immediately available in angular contact types, open or shielded. For further data and detailed test results, ask for BarTemp Data Sheet B-1.

Barden is a major supplier of miniature, instrument, spindle and turbine bearings volume-produced to ABEC 7 tolerances or better

for reliability...specify

BARDEN PRECISION BALL BEARINGS

THE BARDEN CORPORATION, 206 Park Ave., Danbury, Conn. · Pioneer 3-9201
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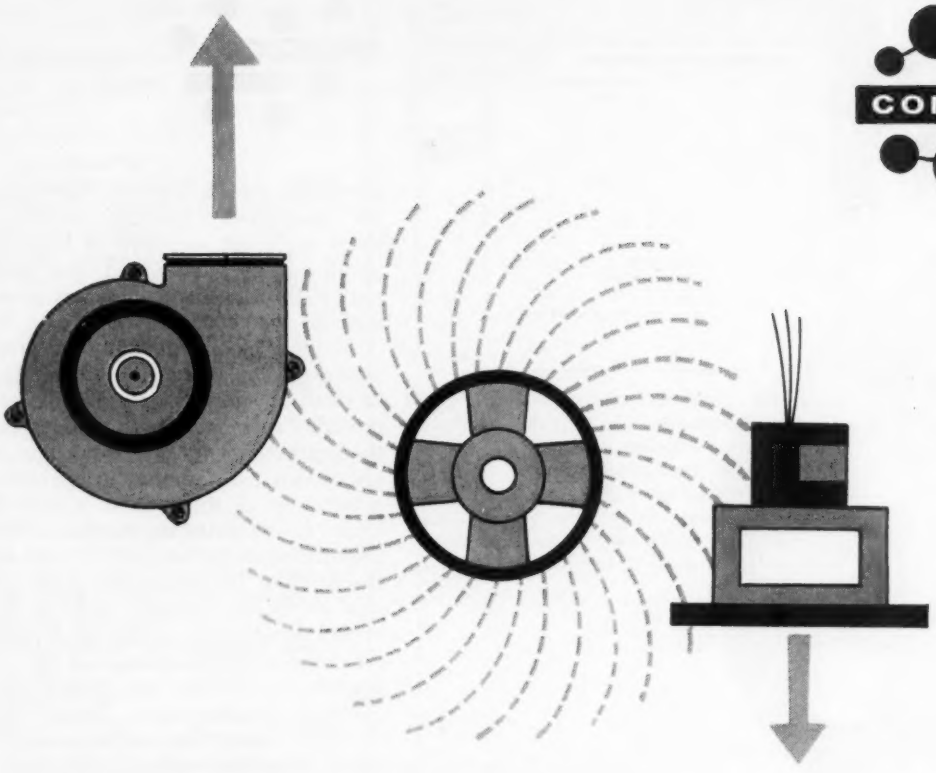
CIRCLE NO. 36 ON INQUIRY CARD

COMPONENTS DIGEST 19



FANS AND BLOWERS

For Cooling Miniature Electronic Equipment

This Components Digest covers selection and application of fans and blowers for cooling miniature electronic equipment. This subject has become increasingly important in recent years as the density of packaging and ambient temperatures have sharply increased. Present trends indicate that fan and blower applications will become even more important in the immediate future.

Probably the most significant recommendation to be made in the application of fans and blowers is to consider the problem early in the packaging phase of instrument design, and not as an afterthought, to be tacked on to a nearly finished piece of equipment. Delayed consideration of cooling can lead to serious problems ranging from the need to use an oversize blower to make up for poor system layout, to a perhaps insoluble (without a major design overhaul) cooling problem with a critical component.

Because safe operation of overall equipment depends so critically on maintenance of adequate cooling, failure of the blower often becomes catastrophic. In effect, the blower should be perhaps the most reliable component in the system. Therefore, any sound blower selection program must include an extremely detailed evaluation of blower reliability, particularly in relation to long life at high ambient temperature. In many applications safety devices are introduced that cut off equipment power if the blower fails to deliver a safe minimum quantity of air.

Other blower selection factors include package size, noise, air delivery under special operating conditions (such as over a wide altitude range), and many aspects of motor performance. Table I presents a complete list of selection factors, many of which will be considered in detail in later sections of this Digest.

STEPS IN DESIGN

In the design of a cooling system, the first step is to layout the components, modules, and other elements so as to provide a reasonably straightforward

TABLE I • Blower Selection Factors

AIR DELIVERY
Volume of air under specified pressure and temperature conditions. Variable air density applications. Weight of air required under the most severe combination of conditions. Back pressure conditions.

TYPE
Centrifugal fan, with forward, straight, or backward curved blades; vaneaxial, tubeaxial, or propeller fan.

POWER SUPPLY
DC or ac, 60 cps, 400 cps, other special frequency, dual frequency, variable frequency, voltage and frequency tolerances, waveform square, sinusoidal, or other, percent distortion. Power supply characteristics indicate choice of drive-motor.

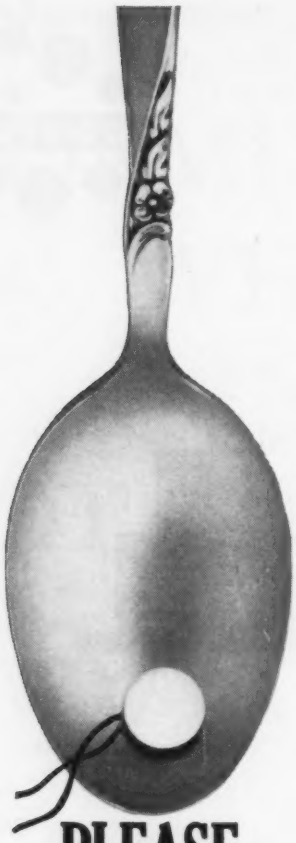
SIZE AND WEIGHT
The largest permissible size means slower speed leading to quieter operation and longer bearing life.

SPEED
Dependent on air delivery requirements and size. Limitations may be imposed by the nature of the power supply. Particular speed ranges characterize different fan types for high efficiency operation in accordance with *specific speed* formula considered elsewhere.

MOUNTING
Mounting means and tolerances

ENVIRONMENTAL REQUIREMENTS
Environmental conditions, particularly the upper temperature limit, under which the blower must operate; life requirements.

AUXILIARY ITEMS
Capacitors, connectors, special switches, spare parts, and other associated hardware which may be called out for separate description in a specification.



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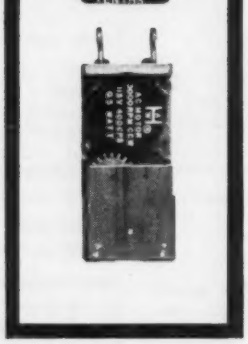

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COMPONENTS DIGEST

flow path for cooling air. Restrictions are minimized. Critical components, those most apt to suffer at high temperatures, are located at the coolest part of the air stream. Regions of stagnant air are avoided.

Because of the difficulty of precise analysis, calculations are used primarily to establish orders of magnitude, or to provide "rules of thumb" to guide in the rearrangement of components and orientation for optimum results. Often a mock-up of the system is desirable where heat sources are employed in an approximation to the final package configuration. Thermocouple tests may lead to design changes until a good overall condition is achieved in which the temperature conditions of all components are within safe limits. Temperature measurements based upon carefully placed thermocouples may be taken for various amounts of cooling air as a basis for establishing blower requirements. Both air delivery and pressure drop as well as temperature rise of the cooling air are significant parameters. Data taken under these experimental conditions may be amplified by analysis to cover all of the temperature and altitude (if required) specifications for the particular equipment. Thus the selection of blower and drive motor may be carried out most accurately.

Where experimental data is not readily available, less accurate estimates must be made to arrive at the specific blower characteristics needed to obtain the required cooling capacity under the most severe cooling conditions, and to finally select the actual blower type and size.

In succeeding portions of this Digest we consider in sequence the steps in:

Arranging elements for most efficient cooling.

Determining specific blower characteristics.

Choosing the actual blower.

Before considering these fundamental steps in detail however, it is advantageous to review the basic facts of air flow circuit design and analysis.

AIR FLOW CIRCUIT FUNDAMENTALS

A rough analogy exists between air flow and the flow of electricity. In both instances there is an impelling force, voltage, or pressure, forcing the circulation of electricity or air through a resistive path. For air flow under steady flow conditions, the analogy is roughly with a nonlinear purely resistive elec-

TABLE II

DEFINITIONS OF MOST SIGNIFICANT AIR FLOW PARAMETERS WITH PRACTICAL UNITS

STATIC PRESSURE
Compressive pressure existing in a fluid; a measure of its potential energy.

VELOCITY PRESSURE
Pressure corresponding to the velocity of flow; a measure of kinetic energy. For frictionless flow it is equivalent to the pressure producing the flow. For standard air density (0.075#/cu ft.)

velocity pressure = v/4005,

where v = ft/min, and pressure = inches of water.

TOTAL PRESSURE
The sum of static and velocity pressures; a measure of the total energy of the fluid.

TOTAL ABSOLUTE PRESSURE
The total absolute pressure is obtained by adding one standard atmosphere (14.696 psi) to the gauge pressure.

VOLUME FLOW RATE
Volume flow of fluid usually expressed in cubic feet per minute.

FAN EFFICIENCY
Ratio of air-power output corresponding to static pressure to shaft power input.

$$\eta_s = \frac{0.117 \times \text{cfm} \times \text{static pressure}}{\text{watts input}}$$

If total pressure is substituted for static pressure, η_T (total efficiency) is calculated.

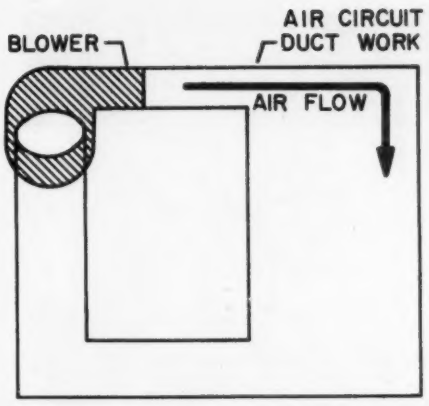

Fig 1 Air flow circuit. Air leaves blower under some degree of compression (static pressure) and with a velocity corresponding to a velocity pressure. Depending upon the degree of constriction in the duct, velocity and static pressures may change from one to the other, but always accompanied by some friction losses.

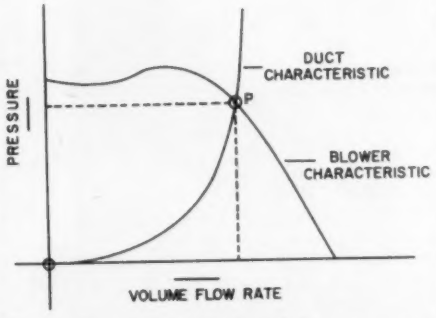

Fig 2 Superposed duct and blower pressure versus volume flow rate characteristics. Point "P" represents the operating point of the system.

trical circuit. Analysis of such circuits is particularly convenient with graphical methods, which are often used in air flow calculations.

The problem in general is to match the blower with the air flow circuit to deliver the required amount of cooling with maximum efficiency. The solution to the problem requires a knowledge of the laws governing blower characteristics and air duct characteristics.

Blowers are characterized by their air flow versus static pressure plots for various fixed values of shaft speed; ducts are characterized by their system resistance curves which show duct static-pressure drop as a function of volume flow rate. Intersection of blower and duct characteristic curves determines the operating point of the combination. Although these curves may apply to some standard atmospheric conditions, they are readily modified in accordance with fan laws described below to apply to widely varying temperature and altitude conditions.

Consider the simple situation of Fig. 1 and Table II where the most significant parameters relating to air flow are defined. In effect the blower "collects" air at atmospheric static pressure (zero gauge pressure), and raises its pressure level, applying the pressure differential to the resistance to air flow presented by the system duct work. High pressure air leaves the impeller in the form of a total (static plus velocity) pressure head. In its turn system resistance (a function of flow rate) adjusts itself so that its pressure drop matches that developed by the blower. The internal resistance of the blower itself results in a loss in developed pressure with increasing flow. For fixed atmospheric conditions (pressure and temperature) and a constant motor speed, typical impeller and air circuit characteristics take the form shown in Fig. 2.

Let us examine the above situation in more detail, paying specific attention to the individual static and velocity pressures. In our reasoning we will assume that the air is essentially incompressible. This is a reasonable assumption since the pressures encountered in air flow circuits depart only by a small percent from atmospheric pressure, resulting in a correspondingly small percent change in air density.

Air leaves an impeller with both static and velocity pressure components

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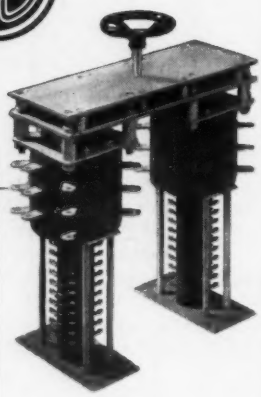
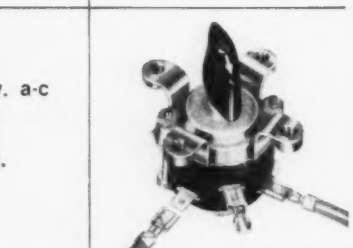
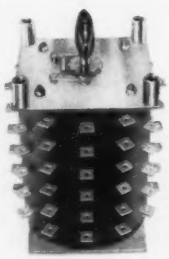
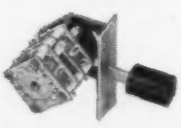
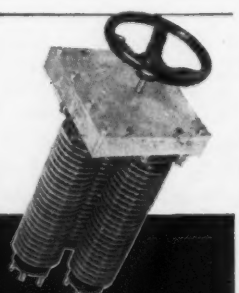
Single-control tandem pair; snap-action; 7 × 19 inches × 20 inches behind panel. 75 lbs. approx.	200 amps. 500 v. a-c 6-pole, triple-throw; 30 amps. 500 v. a-c 20-pole, triple-throw.	
Quick-connect terminaling for snap-on wiring; 3¼ inches diameter, 3 inches behind panel. 8 oz. approx.	10 amps. 125 v. a-c single-pole 4-position; snap action.	
2-way drive by 6-volt solenoids; 3⅞ inches diameter, 18½ inches long. 12 lbs. approx.	10 amps. 125 v. a-c 34 poles, 2 positions.	
High-current low-voltage tap switch; 10¾ × 10¾ inches, 14 inches behind panel. 25 lbs. approx.	150 amps. 6 v. a-c 6-pole 12-position.	
Lever-actuated miniature switch; 1¼ × 1¾ inches. 1¼ inches behind panel. 2 oz. approx.	3 amps. 125 v. a-c 4-pole 3-position.	
3-gang, gear-drive single-control switch; 6⁹⁄₁₆ × 7¹⁄₁₆ inches × 14 inches behind panel. 25 lbs. approx.	5 amps. 125 v. d-c 75 poles 2 positions.	

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CIRCLE NO. 39 ON INQUIRY CARD

COMPONENTS DIGEST

generated as a result of blade rotation in a confined region. The air therefore has the potential energy of compression and the kinetic energy of velocity, which, neglecting losses, may be transformed from the one to the other depending upon the characteristics of the system being cooled. The velocity of air abruptly decreases as air enters a chamber (perhaps an electronics cabinet), the entering velocity being converted to compression, where relatively slow moving air has high potential energy. An exit for the air of narrow cross-section results in an increased velocity, restoring the initial kinetic energy minus friction losses. A substantial constriction at the outlet impedes air flow resulting in a build-up of static pressure in the chamber, reacting with a higher back-pressure on the flow of entering air. Conversions between static and velocity pressure inevitably result in losses, so these conversions should be minimized by appropriate consideration of the geometry of the air flow paths.

Since most of a fan's output is in the form of static pressure, and since the efficiency of conversion of velocity to static pressure is uncertain, it is conservative practice, in most situations, to consider only the static pressure component of fan output energy.

MATCHING THE BLOWER AND AIR CURRENT

As shown in Fig 2, a specific blower and air circuit establish an operating condition such as point "P". The blower should be so selected that "P" is a condition of reasonable efficiency. Of course air delivery should correspond to the system cooling requirements.

One basis of selection has to do with the efficiency with which shaft power at the blower wheel is converted to air horsepower, either total or static. The following formula applies:

$$HP_a = \frac{Qp}{6356}$$

where:

HP_a = air horsepower (total or static)
Q = Volume flow rate (cfm)
P = pressure (total or static)

The efficiency of the blower may be expressed as static or total efficiency:

$$\eta = (HP_a/HP_i) \times 100$$

where: η = efficiency (percent)
HP_i = shaft horsepower

In most applications, engineers prefer to apply the more conservative static efficiency. Because static air horse-

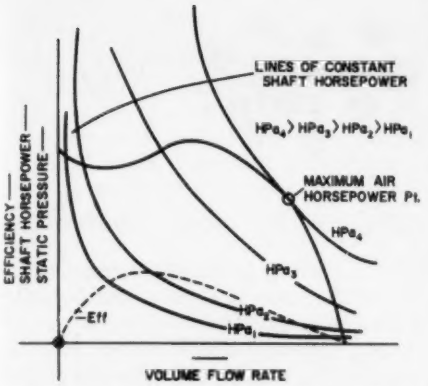

Fig 3 Blower flow characteristics showing a typical static pressure versus volume flow rate, universal air horsepower curves for specific values of air horsepower, and a typical curve of efficiency vs flow rate.

power is fixed by cooling requirements, a major design objective is to minimize power input by choosing a blower that will operate at approximately its maximum efficiency point. Fig 3 relates the air horsepower (static) and motor shaft output to show the maximum efficiency point. Figs 4 and 5 show a greater variety of blower and duct characteristics to illustrate the nature of the parameters that affect the design problem. Note in particular some of the substantially different conditions under which blowers may operate.

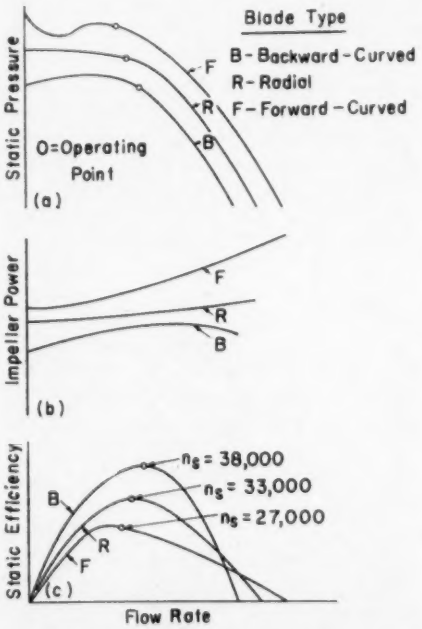

Fig 4 Variation of (a) static pressure (b) power and (c) static efficiency for a centrifugal impeller with various blade shapes. The specific speeds discussed in text indicate typical values for maximum efficiency for the different types.

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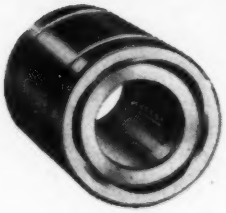

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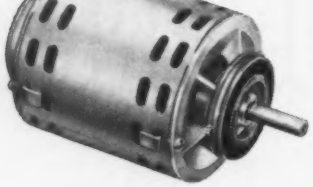

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COMPONENTS DIGEST

ARRANGEMENT OF THE AIR FLOW CIRCUIT

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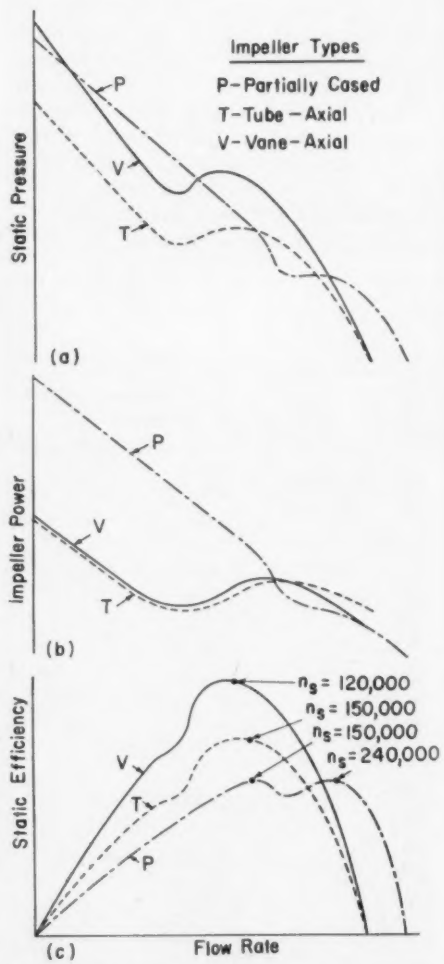

Fig 5 Variation of (a) static pressure, (b) power and (c) static efficiency for axial impellers with various shroud arrangements. The specific speeds discussed in text indicate typical values for maximum efficiency for the different types.

Heat dissipated from a particular surface area depends directly on the area itself and the temperature difference between the surface and the cooling air, as well as a proportionality constant called the forced convection heat-transfer coefficient. This quantity is approximately proportional to a power of the air velocity, the numerical value of the power depending on the type and orientation of the heat dissipating surface. Although forced convection heat-transfer coefficients are almost impossible to calculate directly, except in the simplest systems, when once estimated or measured they may be used in subsequent calculations of system cooling under variable temperature and altitude conditions. Thus, sea level measurements conducted under laboratory conditions lead directly to an understanding of performance under variable environments that affect equipment performance in the field. More will be said about this later when variable altitude operation is examined.

As explained above, forced convection cooling depends upon a power of the air velocity over the surface being cooled; typically the power is about 0.6. Thus, the more cooling required, the greater the required air velocity. The air velocity may be increased at the hot spot by speeding up the blower, thereby increasing the total cfm, or by directing the air by converging the flow at the hot spot. Vanes and baffles assist in this latter method, which is in general the most efficient. The hottest elements should be located as far as possible in the cooler portions of the air stream, near the entering air. Sharp reductions in cross-sections or similar air flow bottlenecks must be avoided.

To increase the area being cooled, good conductive contact must be assured between the heat-generating compossible in the cooler portions of the air stream, near the entering air. Sharp conductively remove heat from tube envelopes to facilitate forced convection cooling. Effectiveness of forced air cooling can be similarly increased by providing fins over which the cooling air is directed. These provide additional heat transfer surfaces which more than compensate for the increased resistance to heat transfer offered by the metal of the fins. The fins should be of a good heat conducting metal and in excellent thermal contact with the heat source.

Electronic assemblies in sealed cases with internal air circulation are frequently used in airborne electronic equipment. An internal blower provides forced air circulation over the electronic parts to transfer heat to the case. Sealed units permit pressuring action which substantially assist the cooling process at high altitudes.

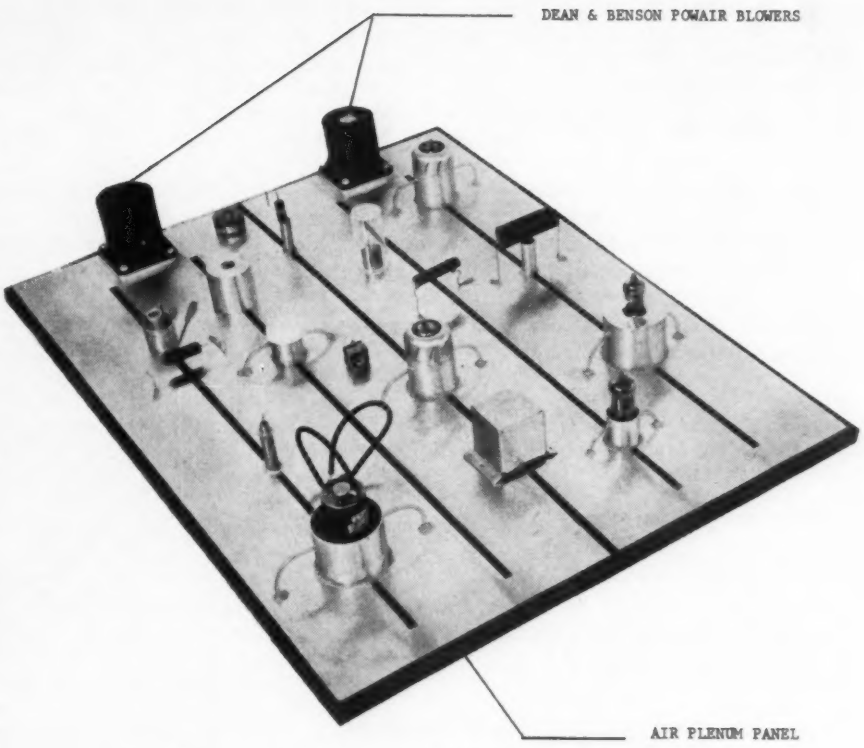

Fig 6 Experimental set-up illustrating method of cooling a plate on which are mounted electronic components.

Some constructions utilize a cold plate heat exchanger comprising a cooled plate, chassis or panel on which are mounted the electronic assemblies and subassemblies. The plate may be cooled by forced air flowing through tubes which are in intimate contact with one side of the plate, or the plate itself may consist of a "sandwich" type heat exchanger through which the air is forced. The heat is transferred from the electronic gear by conduction and natural radiation.

Fig 6 shows an air plenum panel where cooling air is forced through the panel on which are mounted the electronic components to be cooled. Best possible thermal contact is required between these hot components and the panel to avoid hot spots.

HEAT TRANSFER DURING COOLING PROCESS, BASIC RELATIONSHIPS

When cooling air is passed through a piece of equipment heat is absorbed so that the outlet air temperature is higher that the inlet air temperature. The relationship between flow rate in lbs/min, temperature rise, and watts dissipated is given by the expression:

$$\Delta T = C\ (W/M)$$

where ΔT = temperature rise in °C, W = watts dissipated, and M = lbs/min of cooling air. The constant C is inversely proportional to the specific heat of the air and equals 0.132.

An additional significant relationship is given by the *utilization factor*, which is a measure of the effectiveness with which heat is transferred from the heat generating sources to the cooling air. Utilization factor is defined as:

$$\text{Factor} = \frac{\text{Temperature difference between outlet and inlet}}{\text{Temperature difference between heat source surface and inlet air}}$$

The utilization factor is much higher when flow is turbulent than when flow is smooth laminar. For laminar flow layers of hot air are built up in a smooth gradient from the hot surfaces. In turbulent flow these layers are constantly upset for much more efficient heat transfer.

Whether flow is turbulent or laminar is a function of the following variables: weight per minute of cooling air, temperature difference between hot body and cooling air, and the utilization factor. Fig 7 shows whether flow is in the turbulent or laminar region as a function of these variables. A knowledge of this factor is important in certain calculations described later.

When cooling air requirements have been established under standard or an arbitrary set of conditions according to the experimental and theoretical procedures described above, requirements under differing conditions such as at high altitude, are readily established.

With the basic system layout established, and appropriate measurements made of air requirements and temperature rise in an approximately optimum condition, the next step is to pin down

COMPONENTS DIGEST

NOTATIONS USED:

T_I = inlet temperature of cooling air entering the equipment being cooled.

T_O = outlet temperature of cooling air leaving the equipment being cooled.

T_B = body temperature of component being cooled

W = air mass flow

U = air volume flow

Q = heat transferred

$\Delta T_A = T_O - T_I$ = temperature rise between incoming and outgoing cooling air

$\Delta T_T = T_B - T_I$ = available temperature gradient between incoming cooling air and body temperature

UTILIZATION: $\frac{T_O - T_I}{T_B - T_I} = \frac{\Delta T_A}{\Delta T_T}$

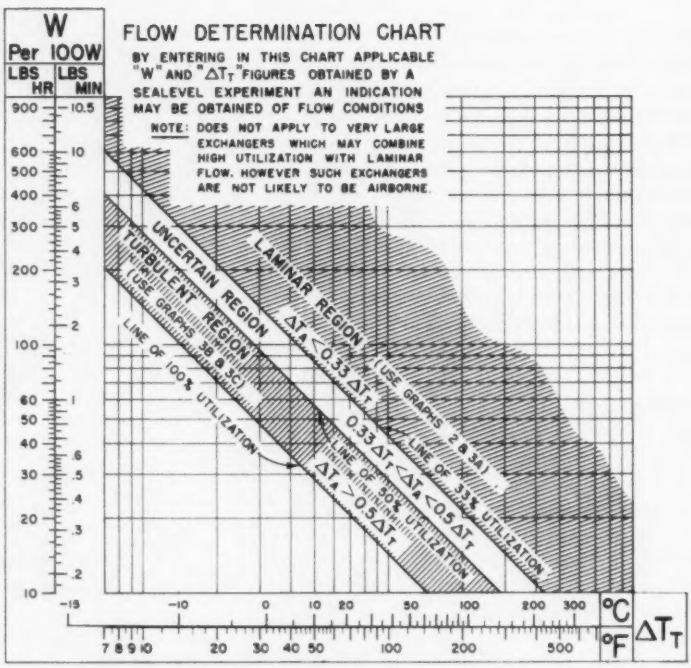
W
Per 100W
LBS HR
LBS MIN
FLOW DETERMINATION CHART
BY ENTERING IN THIS CHART APPLICABLE "W" AND "ΔT_T" FIGURES OBTAINED BY A SEALEVEL EXPERIMENT AN INDICATION MAY BE OBTAINED OF FLOW CONDITIONS
NOTE: DOES NOT APPLY TO VERY LARGE EXCHANGERS WHICH MAY COMBINE HIGH UTILIZATION WITH LAMINAR FLOW. HOWEVER SUCH EXCHANGERS ARE NOT LIKELY TO BE AIRBORNE.
UNCERTAIN REGION
LAMINAR REGION
TURBULENT REGION
USE GRAPHS 2 & 3A
USE GRAPHS 3B & 3C
LINE OF 100% UTILIZATION
LINE OF 33% UTILIZATION
LINE OF 50% UTILIZATION
ΔT_A < 0.33 ΔT_T
0.33 ΔT_T < ΔT_A < 0.5 ΔT_T
ΔT_A > 0.5 ΔT_T
°C
°F
ΔT_T

Fig 7 Nomograph by Rotron for estimating whether flow is laminar or turbulent.

the particular type of blower to be used. Reference is here made to Table I showing size and weight, power supply characteristics, and shaft speed as significant selection factors. The first step is to make a preliminary selection of the most suitable basic types. This problem is somewhat simplified by the far-reaching laws of similitude which apply to impellers of all types. These laws permit impeller characteristics to be viewed on a dimensionless basis for ready comparison of different types, leading to an optimum selection. Size as well as type may be regarded from this universal point of view so that a family of similar impellers may be represented by a single curve with efficiency a definite function of position on the curve. Since operation near the point of maximum efficiency is desirable, the dimensionless parameters corresponding to this point may be translated back to the actual numbers of the problem. Now start by considering *Specific Speed*.

SPECIFIC SPEED

Specific speed is a useful quantity to consider as an aid to blower selection. It may be determined directly from the curve of static pressure versus cfm for a given operating speed. The formula for specific speed is given by the expression

$$N_s = N\ Q^{1/2}/P_s^{3/4}$$

where N_s = specific speed, rpm
P_s = static pressure, inches of water
Q = volume flow rate, cfm

The significance of specific speed is best appreciated by considering certain fan laws described in more detail later. Specifically, if the speed of a blower is increased, cfm will increase as k, while the developed static pressure increases as k^2. A new operating point at the higher speed will have the same efficiency as the original lower speed operating point.

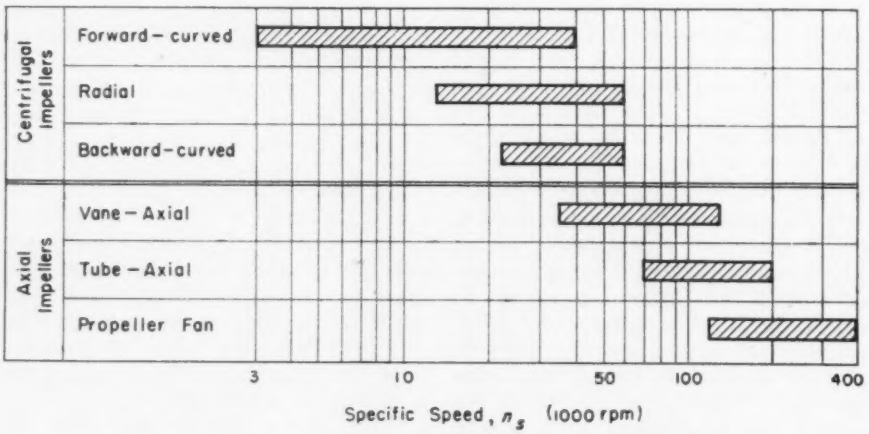

Fig 8 Ranges of specific speed in which six types of centrifugal and axial impellers operate at high static efficiencies.

Notice now that the quantities in the expression for specific speed may be appropriately multiplied by k or k^2 to yield the expression for specific speed at the higher drive shaft rpm. Thus:

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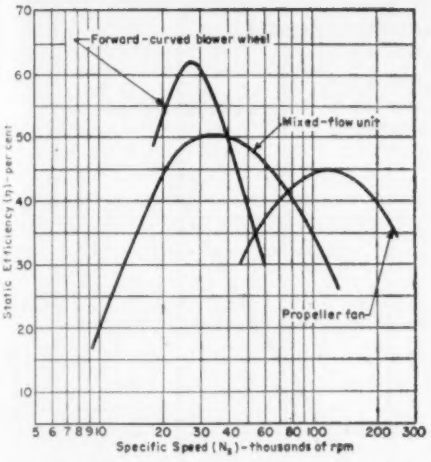
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Mixed-flow unit
Propeller fan
Static Efficiency (η) - per cent
Specific Speed (N_s) - thousands of rpm

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12	600	3,000

In general:

$$N \text{ (theoretical max., or synchronous rpm)} = \frac{120 \times \text{frequency (cps)}}{\text{poles}}$$

COMPONENTS DIGEST

NOTATIONS USED:

T_i = inlet temperature of cooling air entering the equipment being cooled.

T_o = outlet temperature of cooling air leaving the equipment being cooled.

T_s = body temperature of component being cooled

W = air mass flow

U = air volume flow

Q = heat transferred

$\Delta T_A = T_o - T_i$ = temperature rise between incoming and outgoing cooling air

$\Delta T_T = T_s - T_i$ = available temperature gradient between incoming cooling air and body temperature

UTILIZATION: $\frac{T_o - T_i}{T_s - T_i} = \frac{\Delta T_A}{\Delta T_T}$

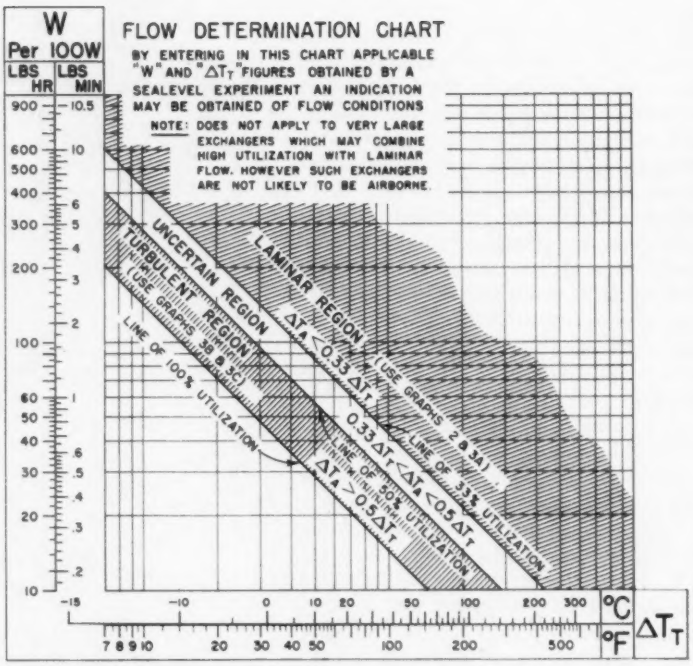
W
Per 100W
LBS HR
LBS MIN
FLOW DETERMINATION CHART
BY ENTERING IN THIS CHART APPLICABLE "W" AND "ΔT_T" FIGURES OBTAINED BY A SEALEVEL EXPERIMENT AN INDICATION MAY BE OBTAINED OF FLOW CONDITIONS
NOTE: DOES NOT APPLY TO VERY LARGE EXCHANGERS WHICH MAY COMBINE HIGH UTILIZATION WITH LAMINAR FLOW. HOWEVER SUCH EXCHANGERS ARE NOT LIKELY TO BE AIRBORNE.
UNCERTAIN REGION
LAMINAR REGION
TURBULENT REGION
(USE GRAPHS 2 & 3A)
(USE GRAPHS 2B & 3C)
LINE OF 100% UTILIZATION
ΔT_A < 0.33 ΔT_T
0.33 ΔT_T < ΔT_A < 0.5 ΔT_T
ΔT_A > 0.5 ΔT_T
LINE OF 33⅓% UTILIZATION
LINE OF 50% UTILIZATION
°C
°F
ΔT_T

Fig 7 Nomograph by Rotron for estimating whether flow is laminar or turbulent.

the particular type of blower to be used. Reference is here made to Table I showing size and weight, power supply characteristics, and shaft speed as significant selection factors. The first step is to make a preliminary selection of the most suitable basic types. This problem is somewhat simplified by the far-reaching laws of similitude which apply to impellers of all types. These laws permit impeller characteristics to be viewed on a dimensionless basis for ready comparison of different types, leading to an optimum selection. Size as well as type may be regarded from this universal point of view so that a family of similar impellers may be represented by a single curve with efficiency a definite function of position on the curve. Since operation near the point of maximum efficiency is desirable, the dimensionless parameters corresponding to this point may be translated back to the actual numbers of the problem. Now start by considering *Specific Speed.*

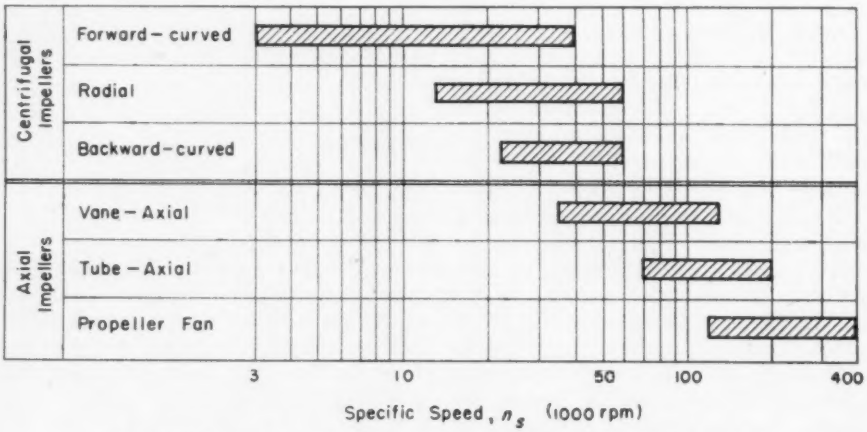

Fig 8 Ranges of specific speed in which six types of centrifugal and axial impellers operate at high static efficiencies.

SPECIFIC SPEED

Specific speed is a useful quantity to consider as an aid to blower selection. It may be determined directly from the curve of static pressure versus cfm for a given operating speed. The formula for specific speed is given by the expression

$$N_s = N\ Q^{1/2}/P_s^{3/4}$$

where N_s = specific speed, rpm
P_s = static pressure, inches of water
Q = volume flow rate, cfm

The significance of specific speed is best appreciated by considering certain fan laws described in more detail later. Specifically, if the speed of a blower is increased, cfm will increase as k, while the developed static pressure increases as k^2. A new operating point at the higher speed will have the same efficiency as the original lower speed operating point.

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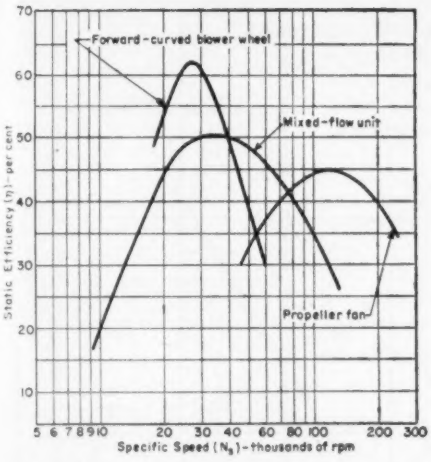
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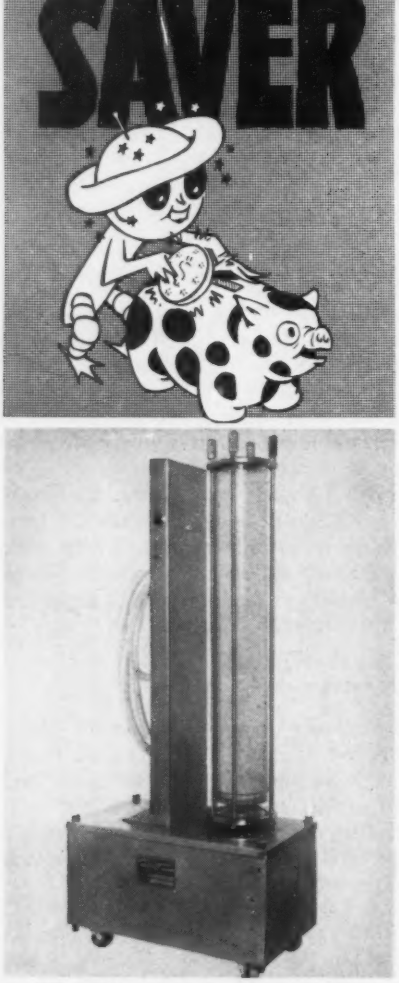

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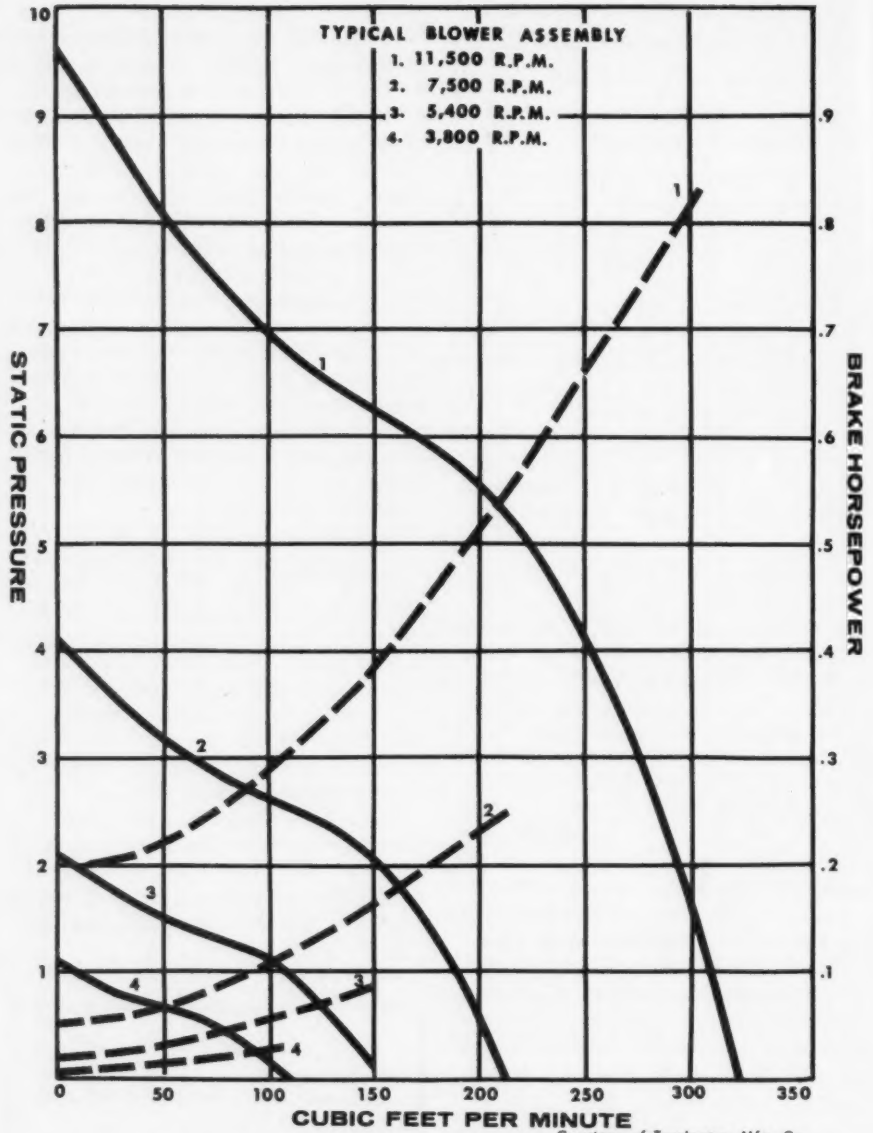
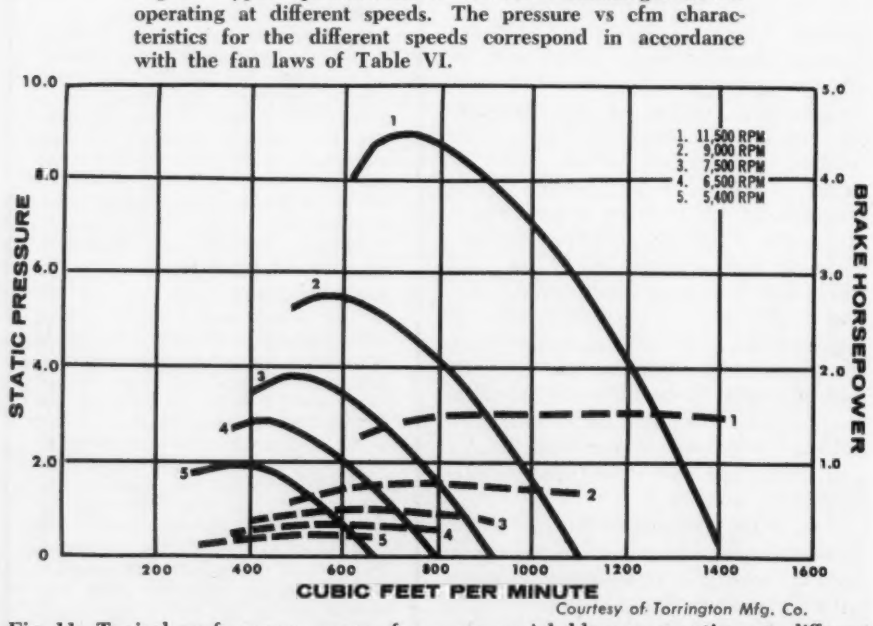


Courtesy of Torrington Mfg. Co.

Fig 10 Typical performance curves for a centrifugal blower operating at different speeds. The pressure vs cfm characteristics for the different speeds correspond in accordance with the fan laws of Table VI.



Courtesy of Torrington Mfg. Co.

Fig 11 Typical performance curves for a vane-axial blower operating at different speeds. The pressure vs cfm characteristics for the different speeds correspond in accordance with the fan laws of Table VI.

lowance for surface roughness and the difficulty of holding tolerances in smaller sizes)

The laws of similitude relating these parameters (briefly mentioned in Table V) are concisely presented in Table VI. These laws are called the *fan laws*, and help apply given fan blades over a wide range of operating conditions differing from the test conditions described by the manufacturer. The universality of these fan laws are a further help in the comparison of fans, and in developing a "line" of fans. The user of blowers and fans would do well to be conversant with these laws. An important precaution is to avoid running a fan above its safe maximum speed.

Fig 12 shows a simple but extremely helpful aid devised by Eastern Air Devices for observing graphically the effects of changes which may be computed by the fan laws as related to conditions of variable air density resulting from changes in altitude or temperature. A particularly valuable feature is the ease of superimposing a motor speed torque characteristic; the intersection of motor and blower curves establishes an operating point. More will be said about this when variable altitude fans are described in a later portion of this Digest.

VARIABLE ALTITUDE OPERATION

When the air delivery requirements for sea-level conditions are known, then the air delivery requirements may be conveniently estimated for high altitude conditions using the convenient formulas presented by Rotron and summarized in Table VII. The table is self-explanatory, showing compactly how to determine the weight of air needed when air density is reduced below the referenced condition. Computations based upon Table VII may be used in conjunction with the EAD chart of Fig 12, which automatically takes into account pertinent Fan laws, to figure horsepower and torque requirements under non-sea-level conditions. The following section considers high-altitude characteristics, particularly as related to the motor, in more detail.

Blowers which operate over a wide altitude range naturally experience a significant reduction in loading in low-density high-altitude air as compared with sea level conditions. It is common practice to recognize this condition in designing blowers for this type of duty.

The most important factors relating to high altitude operation pertain to air density and temperature changes. In effect, temperature change means density change and so these two variables may be combined in the single

TABLE V APPROACH TO BLOWER SELECTION

SUMMARY OF EMPIRICAL PROCEDURE

1. By means of a mock-up system, complete with heat sources and sinks and heat flow paths which approximate the final design, an "optimum" arrangement of components is arrived at. This "optimum" arrangement means a minimum restriction to the overall air flow consistent with packaging requirements, and the placing of critical components most advantageously in the air stream.

2. By means of air flow tests using suitably placed indicating instruments, and thermocouples, significant temperature rise and pressure drop may be measured as a function of the volume of air flow. Temperature of incoming air and outgoing air is measured. Based upon permissible maximum temperatures of critical components, the required cooling air, and corresponding pressure drop are measured. These tests are conducted under sea-level conditions.

(Where operation is required under more severe non-sea-level conditions, corrections to the required figures for pressure drop and air delivery requirements may be applied using the similarity factors of Table VI and VII.) Thus, a specification is now available for required cfm and pressure under the most severe conditions.

3. The best type of blower is now selected. Table III and Fig 8, which show the particular features of each type, are a starting point. The specific speed, whose value depends on air delivery requirements and blower rpm, is a very important guide. The motor must be given consideration at this point in selecting the appropriate rpm. As a starter, several values of rpm may be selected based upon the power supply frequency and the synchronous speeds listed in Table IV. Manufacturer's air delivery vs pressure curves for various types of blowers provide some guide as to the size of blower required as well as the horsepower needed to drive it. The slowest speed for a permissible blower size means quieter, longer-lasting operation. Some trial and error is involved in choosing the proper blower type and then verifying that its specific speed is within a practical range.

4. With the type of blower definitely established, and an approximate idea arrived at as to size and speed, as well as driving horsepower, a calculation of efficiency may be instrumental in resolving several alternatives. There are certain types of fan blades which are fabricated by die-casting, with close tolerances and intricate shapes, providing much more efficiency than inexpensive stamped blades. Cost definitely enters here. On the other hand, the drive motor needs less power and operates much cooler with the high efficiency impeller.

5. Where the manufacturer's data does not cover the specific operating speed selected for the application, the curves may be modified according to the fan laws discussed elsewhere in this Digest, see Table VI. The key factors are:

(a) Multiply cfm by speed increase ratio
(b) Multiply pressure by speed increase ratio squared.
(c) Multiply shaft power by speed increase ratio cubed.

Figs 10 and 11 show how these laws are applied to a typical manufacturer's cfm vs pressure curve to provide a new curve corresponding to the desired shaft speed. Horsepower is also readily obtained. The new curve should result in system operation in the vicinity of its maximum efficiency point. Manufacturer's recommended maximum speed should not be exceeded.

6. Based upon the above procedure a specific motor and impeller are selected. Their performance characteristics may now be rechecked against requirements. Where motor speed changes somewhat as a function of loading, the effects of these changes must be calculated using the fan laws of paragraph 5 above.

TABLE VI

FAN LAW EQUATIONS

SPEED CHANGES
Impeller type, size and air density remain fixed.

$$Q_2 = Q_1 (N_2/N_1)$$
$$P_{s2} = P_{s1} (N_2/N_1)^2$$
$$P_{t2} = P_{t1} (N_2/N_1)^2$$

DENSITY CHANGES
Impeller type, size and speed remain fixed.

$$Q_2 = Q_1$$
$$P_{s2} = P_{s1} (\rho_2/\rho_1)$$
$$P_{t2} = P_{t1} (\rho_2/\rho_1)$$

SIZE CHANGES
Impeller type, speed and density remain fixed; all dimensions change proportionately.

$$Q_2 = Q_1 (D_2/D_1)^3$$
$$P_{s2} = P_{s1} (D_2/D_1)^2$$
$$P_{t2} = P_{t1} (D_2/D_1)^2$$

WIDTH CHANGE (small changes only).
Centrifugal impeller type, size, speed and density remain fixed.

$$Q_2 = Q_1 (L_2/L_1)$$

TABLE VII

COOLING AIR REQUIREMENTS AT VARYING ALTITUDE CONDITIONS

(Condensed from information supplied by Rotron Manufacturing Co., Inc.)

Relationship between altitude and sea-level air flow requirements.

$$W_{ALT} = W_{SEA} (\Delta T_{T\ SEA}/\Delta T_{T\ ALT})^3$$
for laminar flow

$$W_{ALT} = W_{SEA} (\Delta T_{SEA}/\Delta T_{ALT})$$
for turbulent flow

Mass flow W required to absorb Q watts at ΔT_A temperature rise.

$$Q = 0.070\ W\Delta T_A\ (^\circ F)$$
$$Q = 0.126\ W\Delta T_A\ (^\circ C)$$

Relationship between absolute pressure and air density.

$$\rho = 2.70 \times P_{AVE}\ (PSIA)/(460 + T_{AVE})\ (^\circ F)$$
$$\rho = 1.325 \times P_{AVE}\ (Inch\ Hg)/(459.7 + T_{AVE})\ (^\circ F)$$

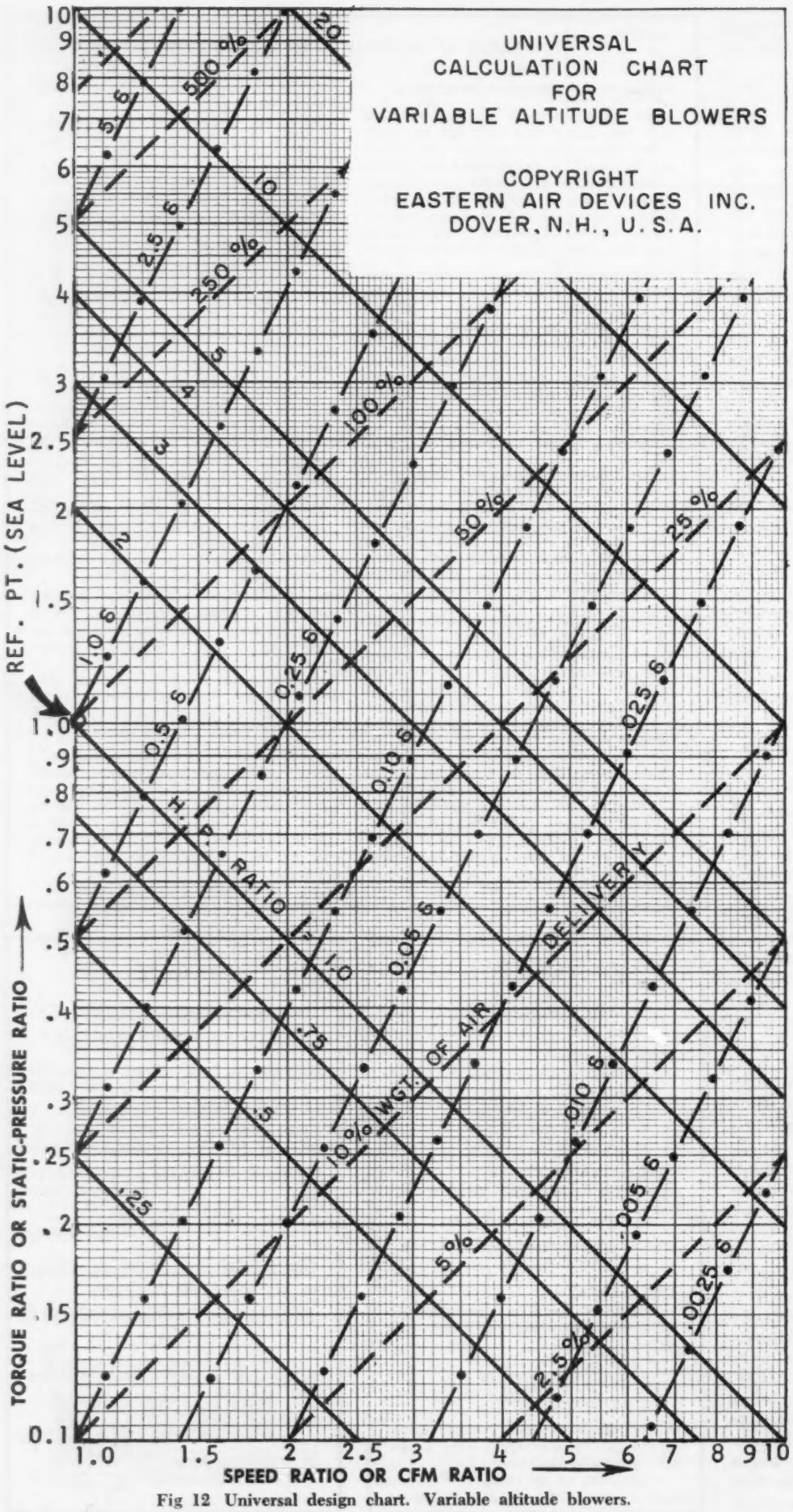


Fig 12 Universal design chart. Variable altitude blowers.

INSTRUCTIONS FOR CHART USE

Eastern Air Devices "Universal Calculation Chart for Variable Altitude Blowers" simplifies the prediction of high altitude operation of a motor-impeller combination when the motor speed-torque characteristic, and the sea-level operating point are known. For simplicity, dimensionless ratios are used throughout. That is, air-density, speed, torque, static pressure, CFM, shaft-horsepower, and weight of delivered air are all shown as a ratio to the corresponding values at sea-level, or *any* reference condition, for that matter. The sea-level reference point occurs on the chart at speed ratio = 1, torque ratio = 1. At this point, relative air density, $\delta = 1$, weight of air delivered is 100%, shaft horsepower ratio = 1, and static pressure and CFM ratios equal unity.

Now superimpose the known speed-torque characteristic of the motor in per-unit values on the chart. Instead of actual speed, plot the speed ratio of actual speed to sea-level or reference speed. Similarly, plot the torque ratio of the known running torque at the speed in question, to sea-level or reference torque. As an illustration, a motor running at 5000 RPM at sea-level with a shaft torque of 2 ounce-inches, and at 20,000 RPM and a torque of one ounce-inch, (from the speed-torque curve) has a point plotted at speed

$(20{,}000/5{,}000) = 4$

and torque = ½.

When the speed-torque characteristic has been completely superimposed in this manner, the operating point at any relative air density, δ, is determined by the intersection of the superimposed curve, and the appropriate air density line. δ is a function of altitude and temperature, and may be determined from standard charts defining this function to suit the specific problem. At the intersection point, shaft horsepower and weight of delivered air may be read directly from the chart. The coordinate axes read directly the ratios of static pressure and CFM to their sea-level value.

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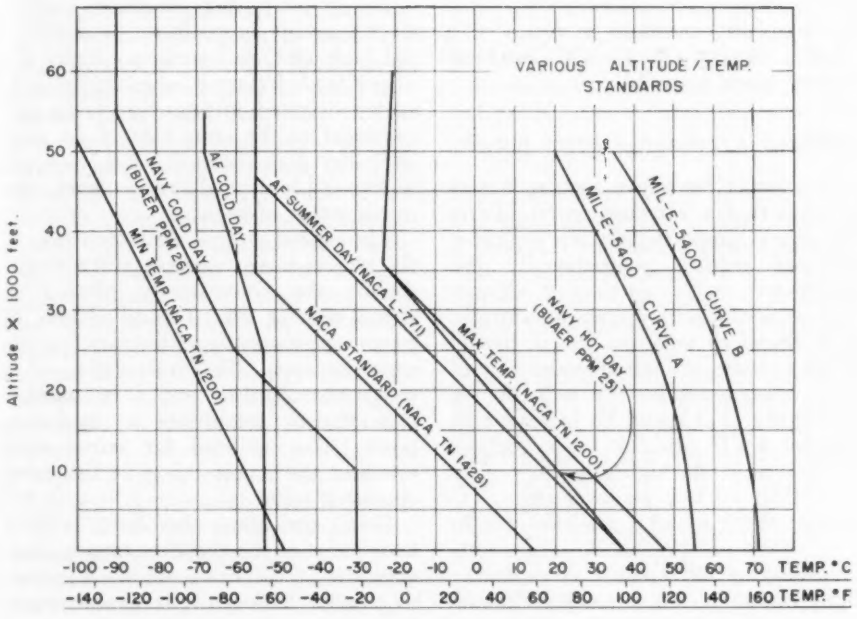
COMPONENTS DIGEST


VARIOUS ALTITUDE / TEMP. STANDARDS
Altitude X 1000 feet
NAVY COLD DAY (BUAER PPM 26)
AF COLD DAY
AF SUMMER DAY (NACA L-771)
MIN TEMP (NACA TN 1200)
NACA STANDARD (NACA TN 1428)
MAX TEMP (NACA TN 1200)
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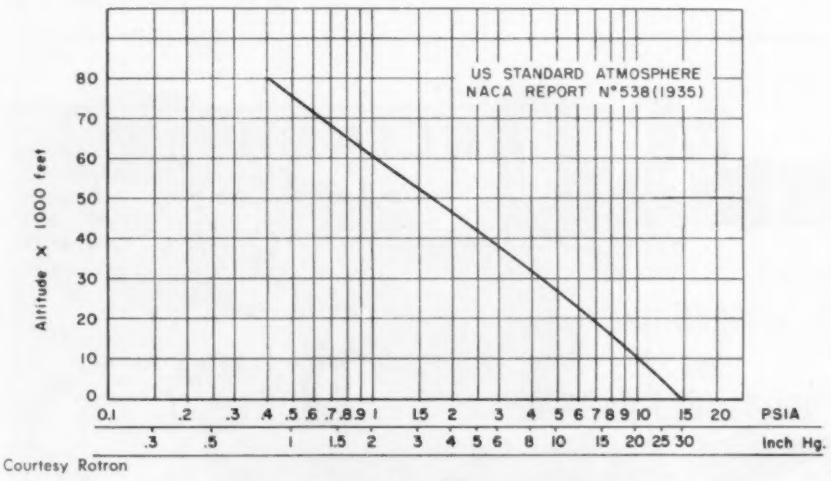
MIL-E-5400 CURVE B
TEMP. °C
TEMP. °F



Courtesy Rotron

Fig 13 Standard altitude-pressure-temperature relationship, as compiled by Rotron.

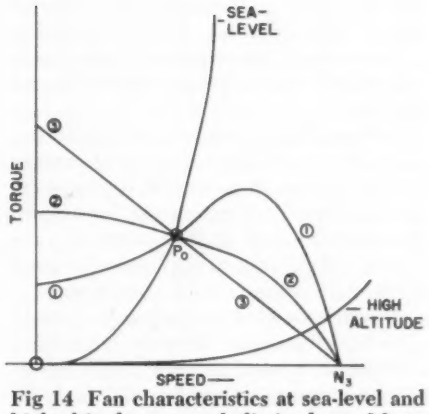


Fig 14 Fan characteristics at sea-level and high altitude are parabolic in shape. Motor speed-torque curves, 1, 2, and 3, correspond to progressively higher rotor resistances. However, all curves intersect at sea-level operating point P_0. The fan performance at intermediate altitudes depends upon the shape of the motor characteristic.

variable of density. Certainly this is the item to consider in blower calculations. Thus we consider a value of density at sea level conditions at a specified temperature, and a high altitude density, including the contribution from any temperature change from the sea level temperature. For constant temperature, density is a simple known function of altitude. Fig 13 shows some of the standardized temperature and pressure versus altitude characteristics assumed to apply by various interested groups.

EFFECT OF AIR DENSITY CHANGES

To determine the effects of changing density on blower performance, the *fan laws*, used for predicting the effects of departures from a set of reference conditions, may be applied. A pertinent fan law states:

> For a constant weight of air, cfm, rpm, and back pressure vary inversely with density.

Thus, if density is reduced to 1/10 of the reference value, rpm must be increased tenfold to deliver a constant

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weight of air (10 x cfm) against a tenfold increase in back pressure. Horsepower corresponding to this condition must increase one hundred times, since horsepower varies jointly with cfm and pressure.

Although this condition is impractical (namely, to deliver a constant weight of air against the tenfold increase in back pressure) it points up the benefit of increased rpm at high altitude.

Let us continue to apply the fan laws to evaluate other useful conditions:

Under constant atmospheric conditions, cfm varies directly with rpm, pressure varies as rpm^2, and horsepower varies as rpm^3.

Thus, if rpm is maintained constant rather than permitted to increase in accordance with the first fan law stated above, at the 1/10 density condition:

Pressure is 1/10 of the sea-level pressure.

Cfm is the same as at sea level.

Horsepower is 1/10 of the sea-level horsepower.

Weight of cooling air is thus 10% of the original reference density condition.

Rather than use the 10:1 sea-level to high altitude density ratio chosen above for convenience in presentation, Table VI describes conditions in terms of a relative density $\delta<1$, with sea-level density taken as unity.

DESIGNING A VARIABLE ALTITUDE BLOWER

In light of the above section, it may be seen that a constant speed blower will deliver proportionally less weight of air and require proportionally less horsepower with decreasing density such as occurs with increasing altitude. It is therefore common to let blower speed increase at high altitudes to partially compensate for the reduction in air density. Let speed be increased by a factor $k>1$. On this basis, recheck the fan laws. At high altitude:

$$\text{Cfm} = k \times \text{sea-level cfm}$$

$$\text{Weight of air} = k\delta \times \text{sea-level weight of air}$$

$$\text{Pressure} = k^2\delta \times \text{sea-level pressure}$$

$$\text{Horsepower} = k^3\delta \times \text{sea-level horsepower}$$

This last grouping of laws, also included in Table VI, tells the whole story .The value of k must depend upon what can be done with the drive motor.

As an interesting condition, assume that constant horsepower is available for high altitude operation. From the above laws, $k^3\delta$ must equal unity, indicating a speed increase inversely proportional to the cube root of air density. For $\delta = 1/10$, $k = 2.16$, a not unreasonable speed ratio from the motor point of view.

The speed-torque characteristics of the blower under variable altitude conditions are conveniently plotted as shown in Fig 14. Typical shapes of motor speed-torque characteristics are super-imposed. The intersection of a motor characteristic and a fan-altitude characteristic establishes an operating point. The sea-level fan curve must intersect the motor curve at the rated operating point.

Using the above fan laws, with a knowledge of the speed vs torque characteristic of the drive motor, it is easy to predict high altitude performance. It is obvious that at a given fan speed the decreasing air density at higher al-

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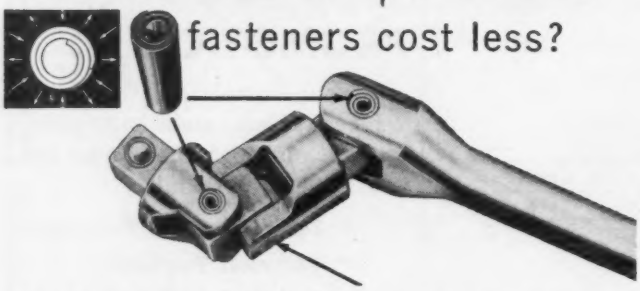

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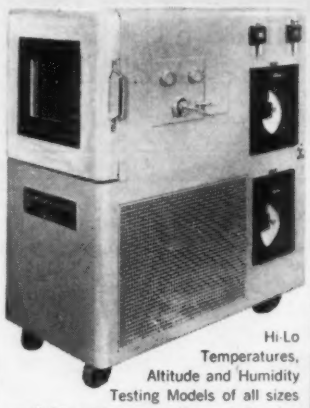

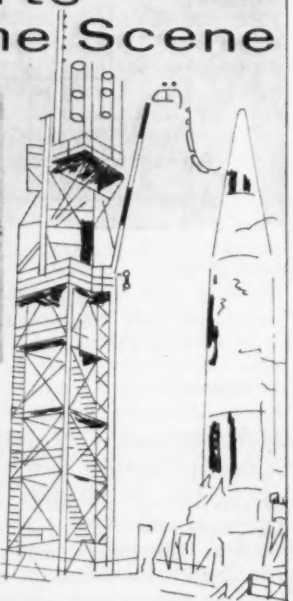

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titudes results in an unloading of the motor; torque requirements fall off. Because of reduced density however, the *weight* of air available for cooling drops off correspondingly. Thus we have a condition where it would be advantageous to increase shaft speed to provide some measure of compensation for the fall off in air density. This is occasionally accomplished by techniques based upon switching in which the motor is converted from a low speed to a high speed machine through reconnection of input lead wires as the loading at high altitude decreases below a certain point. DC machines, such as a series drive motor, by the nature of their speed-torque characteristic tend to provide approximately constant horsepower at reasonable efficiency over a wide speed range. An induction machine, by far the most popular and generally suitable type of drive motor for severe duty under military conditions is inherently unsuitable for variable speed applications.

There are certain basic relations between induction motor output and losses for balanced polyphase operations. Let synchronous speed and slip be defined by the following equations:

$$N_s \text{ (synchronous rpm)} = \frac{120 \times \text{frequency}}{\text{poles}}$$

$$s \text{ (slip)} = \frac{N_s - N}{N_s}$$

where: N = actual rpm

By induction motor theory, if P_{mech} is the motor developed shaft power, then

$$\text{Rotor copper loss, } P_{cu} = \frac{s}{1-s} \times P_{mech}$$

This equation points up the critical and unavoidable relationship between shaft power and rotor copper loss. Consider a numerical example of a 2-pole, 400-cps motor which can run at 21,000 rpm at high altitude when the reduced air density means relatively light loading. At sea-level, high air density loads the drive motor dropping its speed, for example, to 6000 rpm. The slip losses (rotor copper losses) are calculated as follows:

At 21,000 rpm,

$$\text{slip } (s) = \frac{24{,}000\text{-}21{,}000}{24{,}000} = \tfrac{1}{8}$$

At 6,000 rpm,

$$\text{slip } (s) = \frac{24{,}000\text{-}6{,}000}{24{,}000} = \tfrac{3}{4}$$

Then,

Rotor copper loss at 21,00 rpm = (1/8/1-1/8) x shaft power
= 1/7 x shaft power

Rotor copper loss as 6,000 rpm
= 3 x shaft power

These figures are typical, not exceptional. While relatively light losses are encountered at high altitude, rotor copper losses may be several times the shaft power output at sea level. Although motor cooling is better at sea-level, this advantage is insufficient to compensate for high losses. The sea-level condition sets the limit to overall performance. Furthermore, it is not feasible to increase the horsepower capability at sea-level to raise speed to a much higher value, thereby cutting the slip loss. For example, raising the speed from 6,000 rpm to say 18,000 rpm at sea-level would require a 3³ or 27-fold increase in the horsepower capability of the drive motor, almost always an impractical condition. Furthermore, the extremely overpowered motor may then overheat in the thin high altitude air.

In some applications a constant speed drive motor, for example, a 21,000 rpm, 2-pole, 400-cps machine, may be

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coupled to the fan by means of a magnetic slip clutch. This transfers the losses occurring in the motor rotor to the clutch, not substantially affecting the overall efficiency. However, the heating in the clutch is more easily dissipated than heat in the motor rotor. In particular the temperature of the bearings is reduced, which means longer life in this most critical (from the reliability point of view) part of the drive motor.

In choosing a motor for variable altitude operation it is necessary to specify a speed-torque characteristic in which substantial speed increases occur uniformly as the shaft is unloaded. For induction machines the shape of the speed-torque characteristic is largely governed by the resistance of the rotor. Fig 14 shows characteristically how the torque vs speed plot changes its shape as rotor resistance is increased. The figure shows the linear characteristic recommended for the variable altitude application.

DESIGNING FOR ADVANCED APPLICATIONS

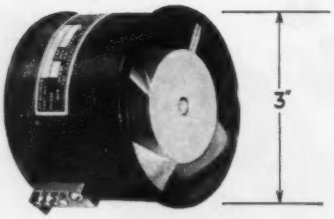
Comments in this and the following sections regarding current problem areas and trends were submitted by Rotron Mfg. Co., Inc.

Cooling as an Afterthought. Electronic designers are so engrossed in their electric circuits that cooling problems are too often postponed to the tail end of the project, when the opportunities for applying effective cooling are lost. Cooling applied as a brute force afterthought means unwieldy volumes and high pressure drops, spoiling a clean mechanical design by requiring large and noisy blowers. Poor heat transfer conditions inside an apparatus may easily double the required air volume, entailing an 8-fold increase in HP, nearly all of which is expended in mechanical losses within the equipment.

High Locations. There is a growing but insufficient awareness that a piece of equipment which is adequately cooled at sea level may very well run into trouble due to overheating when used by a customer located at some altitude such as at 6000 ft in Denver, Colorado. Operations at 6000 feet may mean a 50% increase in HP to give the same cooling as at sea-level.

Overcooling Is A Liability. The designer who adds a fan to his equipment "just to be safe" or the designer who feels himself on insecure ground and specifies fan performance with a goodly "safety margin" may not be doing his ultimate customer a service. A piece of rotating equipment in an otherwise electronic environment brings in the element of service. It also inevitably brings in dust. A dust filter may make conditions *worse;* not only does the filter not remove *all* the dust, but, if the filter is not serviced, it may clog after which the electronic components may burn out. Rotron suggest as a good rule, "Don't use forced cooling if you can avoid it!"

"Scientific" Design. Unfortunately, knowledge of aerodynamics and heat dissipation required to solve cooling problems properly is not possessed by many electronic engineers who must, of necessity, devote most of their time to strictly electronic endeavors. Nor do electronic laboratories have the required facilities for equipment testing. This greatly complicates the problem



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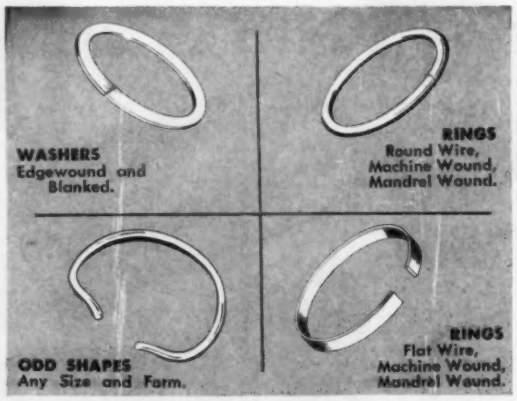

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of designing on a "factual" rather than a guess-work basis. Close cooperation between cooling equipment manufacturer and customer is required.

Reliability. Rotron says that a key factor in poor reliability of some electronic equipment is lack of interest on the part of prime contractors and designers in the operation of cooling devices. They therefore fail to write meaningful procurement specifications. Rotron further comments that significant advances in reliability will go hand-in-hand with greater cooperation in the design stages between the prime contractor and the cooling device manufacturer. The prime contractor will have to make a deliberate effort to work with the manufacturer to make a solid, long-range investment in quality.

CURRENT TRENDS IN BLOWER DESIGNS

400 CPS. Increasing use of 400 cps power supplies allows replacement of dc commutator driving motors by more reliable induction motors.

Smaller Motor Frames. Many manufacturers are introducing motor frames down to ¾ inch diameter, aiding miniaturization of blowers and fans. The high manufacturing cost of such motors, however, makes them uneconomical for cooling of commercial electronic equipment.

Integral Devices. Some manufacturers are venturing into truly integrated air moving devices with motor and impeller designed as an integral compact assembly.

Ambient Temperature Requirements. Revised military specifications, particularly those for aircraft, have given rise to more severe requirements of higher ambient temperatures, lower densities, (higher altitudes with reduced motor cooling and increased loss of lubrication due to evaporation) and also for more rigid provisions against salt spray, sand, and vibration, particularly high frequency vibration.

Standarization. Although several initial moves toward standardization have been made by government agencies, none has materialized. In view of the considerable and successful effort by a few manufacturers to improve the art by introducing a whole series of new design concepts, this lack of standardization may have been beneficial.

The last few years have shown some voluntary standardization by industry in following new mechanical mounting dimensions pioneered by one of the largest manufacturers. This covers the use of 2 opposing mounting flats on certain sizes of electric motors and use of servo-motor type mounting shoulders on opposite ends of axial fans.

Special Fluids. Since water cooling of vacuum tubes has been virtually replaced by air cooling since World War II, a new trend is discernable in cooling fluids. Gases of high heat capacity and density (pressure) have been introduced, requiring fans and blowers of quite different performance characteristics, not rated on the basis of "standard air". Rotron anticipates that the following design factors will be of increasing importance in the future.

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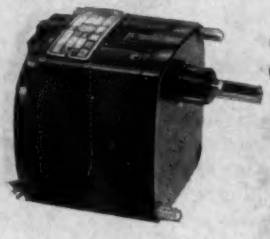

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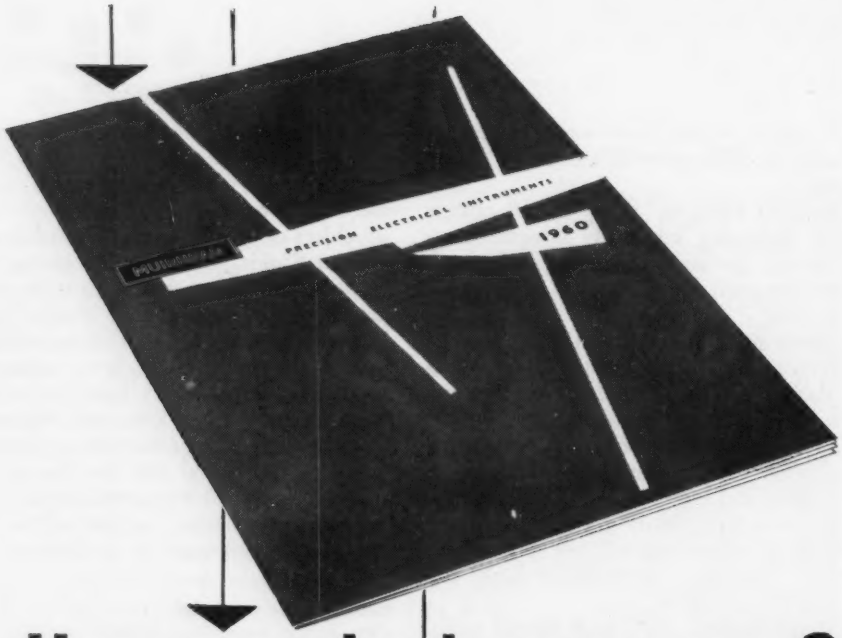

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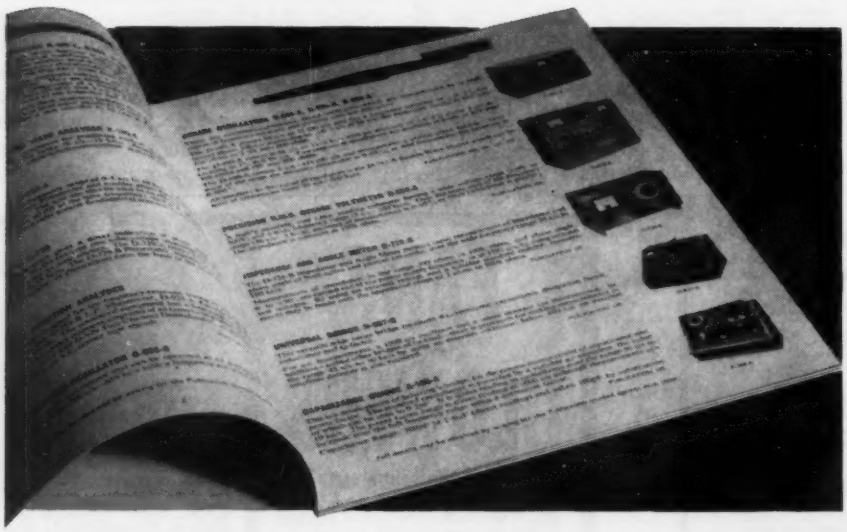

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FUTURE PROBLEMS

Air Filters. Too many products on the market require a disproportionate amount of the user's attention to keep them in good operating condition. Outstanding items are bearings and dust filters. Technical improvements in dust filters are urgently needed. The 85% or 95% efficient dust filter still allows deposits of an impressive amount of foreign matter inside electronic equipment.

Integrated Designs. Further advances in performance, utility and value of cooling devices require increased functional integration of parts, which is a general trend in industry.

Diversification. With steady growth of the electronics industry, manufacturers of cooling devices may find it profitable to invest in diversification to cover every requirement of the industry.

Thermoelectric cooling. Indications are that practical thermoelectric cooling may not be too far off; its advent would certainly open up new avenues for cooling electronic enclosures.

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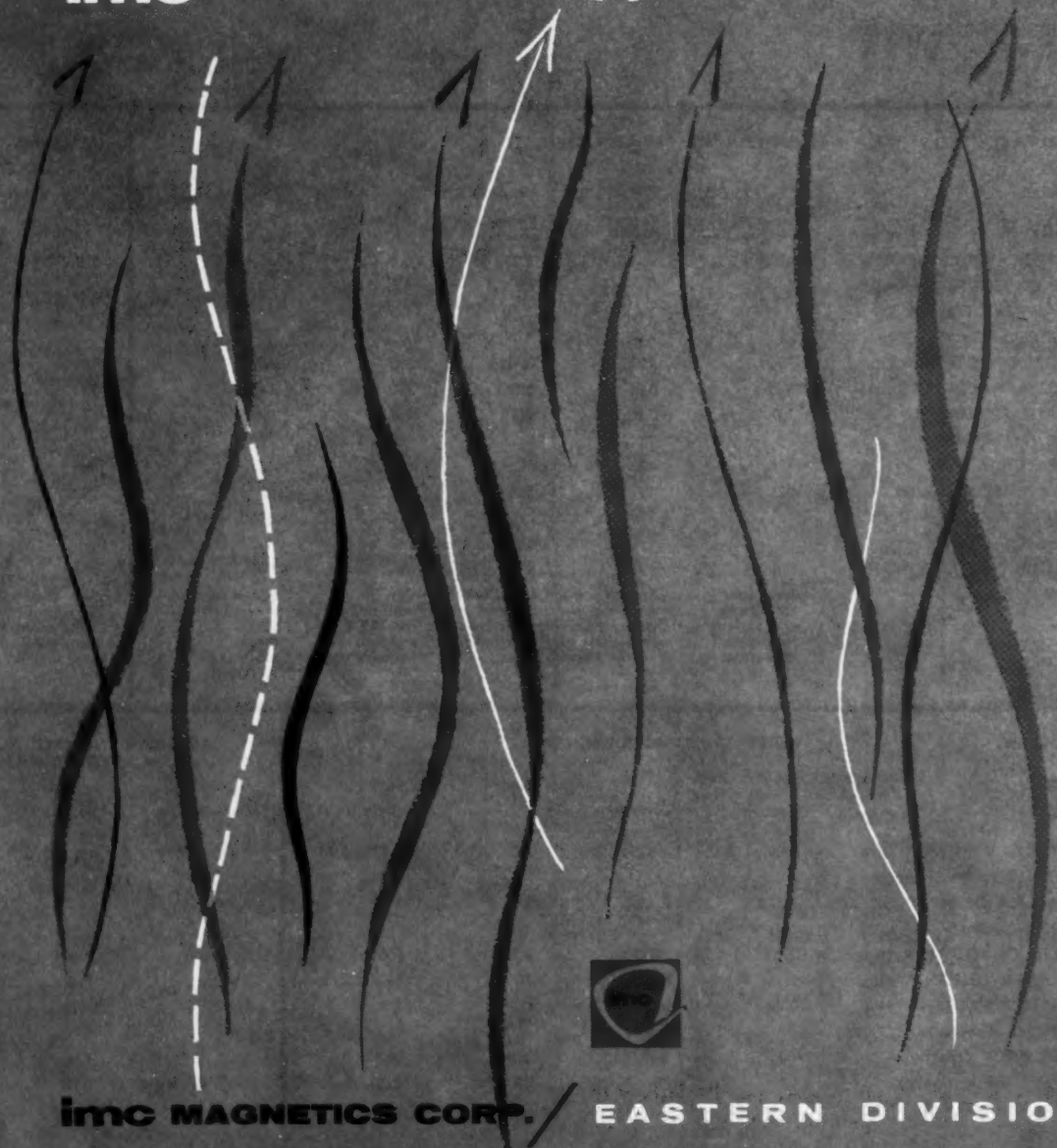

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2. MODEL	F 338-1	FV7-1	F2-23	F2-3	F2-17C	F3-3	B112-3
3. BASIC TYPE	Tube Axial	Vaneaxial	Vaneaxial	Propeller Fan	Tube Axial	Propeller Fan	Centrifugal
4. APPROX. WIDTH OR DIAMETER, LENGTH (inches)	3.60, 3.75	8.50, 5.9	2.16, 2.76	1.45, 2.56	2.16, 2.12	1.45, 2.56	2.9, 3.2
5. DIAMETER OF BLADE OR WHEEL (inches)	3.375	7	2	2	2	3	1.5
6. SPEED OF ROTATION (rpm)	11000	7300	14500	11000	17000	8500	10500
7. FREE AIR DELIVERY (cfm)	110	600	37	25	45	80	16
8. STATIC PRESSURE AT NO AIR (in. of water)	....	....	....	....	....	....	....
9. FREQUENCY (cps)	400	400	DC	400	DC	400	400
10. POWER INPUT (watts)	....	....	....	....	....	....	....
11. LIFE AT MAXIMUM TEMP. (hours)	1000 at 71C	2000 at 85C	500 at 85C	1000 at 105C	500 at 85C	1000 at 105C	1000 at 71C
12. MILITARY OR INDUSTRIAL	Mil	Mil	Mil	Mil	Mil	Mil	Mil
13. REMARKS		Thermal protector	Radio Noise Filter		Radio noise filter		

1. COMPANY	EASTERN AIR DEVICES, DOVER, N. H.					BARBER-COLMAN CO., ROCKFORD, ILL.	
2. MODEL	T 4J92N-3CC	VIHJ-G8-3C	B9HA-E3-2C	B5GA-L3-2CC	F3HJ-M5-2CC	BYLM 42530-1	AYFA
3. BASIC TYPE	Tube Axial	Vaneaxial	Centrifugal	Centrifugal	Propeller Fan	Centrifugal	Propeller Fan
4. APPROX. WIDTH OR DIAMETER, LENGTH (inches)	4.75, 4.25	2.125, 1.500	7.93, 11	6.5, 7.3	4, 1.919	2.88, 3.19	....
5. DIAMETER OF BLADE OR WHEEL (inches)	4	1.625	4.125	1.875	4	1.5	3-8
6. SPEED OF ROTATION (rpm)	7200	20000	3300	3350	4500	10900	75-1080
7. FREE AIR DELIVERY (cfm)	125	64	600	110	140	17	....
8. STATIC PRESSURE AT NO AIR (in. of water)	1.0	3.0	2.5	1.5	0.8	....	....
9. FREQUENCY (cps)	400	400	60	60	400	DC	60
10. POWER INPUT (watts)	30	40	550	30	65	20	8-103
11. LIFE AT MAXIMUM TEMP. (hours)	....	1000 at 125C	....	5000 at 71C	3000 at 105C	1000 at 200 F	....
12. MILITARY OR INDUSTRIAL	Mil	Mil	Mil	Mil	Mil	Mil	Industrial
13. REMARKS	Available for 60 cps and variable frequency operation.	Speed can be made to increase with decreasing air density.	Input watts reduced under static pressure conditions.	Can be modified for 125 C ambient temperature	Speed increases to 23000 rpm at an altitude of 70,000 ft.	Four blower sizes and three motor sizes available in this series.	Above figures vary depending on fan & motor combinatio

1. COMPANY	RIPLEY CO., MIDDLETOWN, CONN.				AMERICAN STANDARD, BLOWER DIV., DETROIT, MICH.		
2. MODEL	8437	81	8442	8452	H-105814	K-16681	H-129596
3. BASIC TYPE	Centrifugal	Centrifugal	Dual Centrifugal	Centrifugal	Centrifugal	Vaneaxial	Axial
4. APPROX. WIDTH OR DIAMETER, LENGTH (inches)	2.94, 4.56	4.625, 5.80	3.55, 5.69	6.375, 6.75	8.34, 11.625	10, 9.875	5.125, 6
5. DIAMETER OF BLADE OR WHEEL (inches)	1.5	2.75	2	3	4.5	....	....
6. SPEED OF ROTATION (rpm)	3150	3100	3000	6000	3450	11300	11000
7. FREE AIR DELIVERY (cfm)	5	60	20	150	250	250	180
8. STATIC PRESSURE AT NO AIR (in. of water)	0.09	0.52	0.26	3.9	1.1	13.8	6
9. FREQUENCY (cps)	60	60	60	ac/dc	60	400	400
10. POWER INPUT (watts)	15	40	18	120	1/12 HP Motor	1 HP Motor	1/2 HP Motor
11. LIFE AT MAXIMUM TEMP. (hours)	....	....	....	....	....	....	....
12. MILITARY OR INDUSTRIAL	Mil	Mil	Mil	Mil	Mil	Mil	Mil
13. REMARKS	Life expectancy of several years with continuous duty.					For high pressure, low volume performance.	

CHARACTERISTICS OF FANS AND BLOWERS

TORRINGTON MFG. CO., SPECIALTY BLOWER DIV., TORRINGTON, CONN.

MSA-10605	MSA-11239	MSA-11050	MSA-11149	MSA-9631
Propeller	Tube Axial	Tube Axial	Vaneaxial	Centrifugal
7.62, 4.87	10.15, 6.96	3.44, 3.50	12.12, 11.57	5.52, 6.75
6	9	3	10	4
1125	3500	3600	7500	9000
100	1000	32.2	3450	230
0.16	2.40	0.38	6.2	5.2
60	DC	60	DC	AC/DC
35	110	2	....	....
....	....	2000 at 150C	....	....
Mil	Mil	Mil	Mil	Mil

DEAN & BENSON MFG. CO., KANSAS CITY, MO.

CR1-1	HF3-2	MF3-1	HP2-3
Axial	Vaneaxial	Vaneaxial	Vaneaxial
2.6, 4.25	3, 2.25	3, 2.25	3, 2.25
....	2.5	2.5	2.5
3450	22000	11000	15000
160	63.5	25	21
1.08	4.0	0.95	2.8
400	400	400	DC
....	96	14	11
5000-10000	2000	3000	3000
Mil	Mil	Mil	Mil

ROTRON MFG. CO., WOODSTOCK, N. Y.

Propimax 2	Aximax 3	Muffin fan	Aximax 1	Aximax 2
Propeller Fan	Vaneaxial	Propeller Fan	Vaneaxial	Vaneaxial
3, 1.5	3.25, 2.375	5, 5	1.5, 1.5	2, 1.5
....	....	....	....	....
21500	22000	3100	22500	20800
120	162	100	23	60
3.5	4	0.3	1.5	3
320-1600	320-1200	50-60	400/800	250-1760
16-38	23-130	14	5.5-31	11-38
1000 at 125C	1000 at 125C	26280 at 110C	1000 at 125C	1000 at 125C
Mil	Mil	Industrial	Mil	Mil
Speed increases with altitude. For cooling electronic equipment in tightly packed black boxes in aircraft and missiles.		Flushing electronic black boxes, office and industrial machinery		Speed increases with altitude. For cooling electronic equipment in tightly packed black boxes in aircraft and missiles.

GLOBE INDUSTRIES, DAYTON, OHIO

C19A-524	19A566	19A751	19A652
Axial	Centrifugal	Vaneaxial	Axial
2.625, 3.91	2.31, 2.30	3, 2.25	2.25, 2
2.5	1	2	2
11000	10000	....	16000
58	5.2	170	50
0.8	0.5	5.75	2.3
DC	DC	400	400
16	6	130	30
....	....	....	1000 at 71C
Mil	Mil	Mil	Mil
Radio noise filter	Radio noise filter	For high temperature and pressure applications.	Available for 125C temp. operation.

IMC MAGNETICS CORP., WESTBURY, N. Y.

BC905F	BC1615B-19	BT910B	BC1307V-2	BC1307F-6	BT3830B-4
Propeller Fan	Dual Centrifugal	Centrifugal	Vaneaxial	Propeller Fan	Centrifugal
1.5, 1.75	2.94, 4.78	1.98, 2.80	2.625, 2.125	2.375, 3.375	10.375, 10.94
1.5	1.75	1	2	2	4.5
18000	3000/7000	10500	17000	10000	3350
18	22	6.25	50	42	750
0.53	0.65	0.62	3.2	1.6	4.5
400	60-400	400	400	380/420	60
7	11/22	8	67	11	600
....	....	....	....	....	....
Mil	Mil	Mil	Mil	Mil	Mil
Can be designed so that speed increases with altitude.				Operates at altitudes to 50,000 feet.	

ASHLAND ELECTRIC PRODS., LONG ISLAND CITY, N. Y.

A4H95Q-1C	C5N3J-1CC	C5D2Q-1C
Axial	Centrifugal	Centrifugal
5.31, 4.06	3.81, 5.05	4.17, 4.43
4	2.5	2
3300	Variable	3600
107	50-110	20
0.25	1	0
60	400	50/60
10	90	19
10000 at 85C	1000 at 95C	5000 at 65C
Mil	Mil	Industrial
Flushing cabinets at moderate pressure	CFM increases with altitude	Cooling orthicons in T.V. cameras

Summary of Performance Characteristics of Fans and Blowers (Continued)

1.	COMPANY	KOOLTRONIC FAN CO., PRINCETON, N.J.			REDMOND CO., OWOSSO, MICH.		
2.	MODEL	A4030	KBB30	KB451MB	3802	TW-2402-PX	3866	AO-4401-AX
3.	BASIC TYPE	Propeller	Centrifugal	Propeller Fan	Centrifugal	Centrifugal	Centrifugal	Dual Centrifugal
4.	APPROX. WIDTH OR DIAMETER, LENGTH (inches)	6.44, 12.44	5.5, 6	6.25, 4.44	8.81, 3.94	8.25, 7.39	8.25, 7.03	8.25, 11.06
5.	DIAMETER OF BLADE OR WHEEL (inches)	....	3	4.5	5.25	4.75	5.25	5.25
6.	SPEED OF ROTATION (rpm)	3450	3100	3350	1400	2050	1550	1500
7.	FREE AIR DELIVERY (cfm)	275	86	98	100	200	160	400
8.	STATIC PRESSURE AT NO AIR (in. of water)	1.0	0.125	....	0.45	1.5	0.6	0.6
9.	FREQUENCY (cps)	60	60	60	60	DC	60	60
10.	POWER INPUT (watts)	....	....	....	55	60	63	150
11.	LIFE AT MAXIMUM TEMP. (hours)	....	....	....	....	....	....	....
12.	MILITARY OR INDUSTRIAL	Industrial	Mil	Mil	Industrial	Industrial	Industrial	Industrial
13.	REMARKS				Can be modified for military use	....	....	....

1.	COMPANY	AIR-MARINE MOTORS, AMITYVILLE, N. Y.					SANDERS ASSOCIATES, INC. NASHUA, N. H.
2.	MODEL	A1221-35	E2243-4	A5264-9	E2243-6	E2223-3	2A
3.	BASIC TYPE	Propeller Fan	Propeller Fan	Propeller Fan	Propeller Fan	Propeller Fan	Centrifugal
4.	APPROX. WIDTH OR DIAMETER, LENGTH (inches)	5.875, 3.875	5.875, 4.97	5.875, 4.22	5.375, 3.625	5.375, 3.59	1, 1
5.	DIAMETER OF BLADE OR WHEEL (inches)	4.5	4.5	4.5	4	4	0.875
6.	SPEED OF ROTATION (rpm)	3250	11400	4000	11400	7600	20000
7.	FREE AIR DELIVERY (cfm)	105	395	140	265	175	2.2
8.	STATIC PRESSURE AT NO AIR (in. of water)	0.36	3.4	0.31	3.4	0.86	0.9
9.	FREQUENCY (cps)	60	400	320-1000	400	400	400
10.	POWER INPUT (watts)	12	200	31	92	79	....
11.	LIFE AT MAXIMUM TEMP. (hours)	....	....	....	....	....	500 at 110C
12.	MILITARY OR INDUSTRIAL	Mil	Mil	Mil	Mil	Mil	Mil
13.	REMARKS					High Altitude Applications	Speed increases with increasing altitudes

1.	COMPANY	HEINZ MUELLER ENGRG. CO., CHICAGO, ILL.			HEINZE ELECTRIC CO., LOWELL, MASS.			
2.	MODEL	BL-100	BL-200	ES-16965-2	D2 1/2 d	SMR 115	YSD	D25
3.	BASIC TYPE	Centrifugal	Centrifugal	Propeller Fan	Centrifugal	Centrifugal	Dual Centrifugal	Centrifugal
4.	APPROX. WIDTH OR DIAMETER, LENGTH (inches)	2.312, 1.766	3.75, 3.77	2.5, 2.281	4.375, 5.69	5.25, 6	6, 7.17	3.75, 4.875
5.	DIAMETER OF BLADE OR WHEEL (inches)	1	2	2.125	2	3.81	3.81	2
6.	SPEED OF ROTATION (rpm)	8000	8000	10000	3100	2800	1650	3100
7.	FREE AIR DELIVERY (cfm)	3	28	42	34	105	110	10
8.	STATIC PRESSURE AT NO AIR (in. of water)	....	....	....	....	2.3	0.39	....
9.	FREQUENCY (cps)	ac/dc	ac/dc	ac/dc	50/60	ac/dc	50/60	50/60
10.	POWER INPUT (watts)	1.5	10	10	1/150 HP Motor	1/15 HP Motor	1/200 HP Motor	1/150 HP Motor
11.	LIFE AT MAXIMUM TEMP. (hours)	....	....	....	....	....	....	....
12.	MILITARY OR INDUSTRIAL	Mil	Mil	Mil	Mil	Industrial	Mil	Mil
13.	REMARKS			Radio noise filter	Durable plastic housing withstands 230 F.	High output where quiet operation is not essential.		Durable plastic housing withstands 230 F.

New Components For Electromechanical Systems

Reset Timer

Designed primarily for flush mounting, an integrally-designed plug-in timer is installed by cutting one 3⅛ inch diameter opening. The timer itself may be removed and replaced from the permanently mounted case at any time in five seconds or less. The resent timer contains four separate and independent load contacts, two of which are instantaneous and may be used as relays. Each load contact, being separate and independent of the other, provides hundreds of practical control combinations, in many instances eliminating other costly components. Eagle Signal Co., Moline, Ill.

Write No. 723 in Box on Inquiry Card

Formfitting Batteries

Curved for optimum space utilization in missiles, a high-rate two-section primary battery was designed for wide variations in discharge rates (as high as 100 amps continuously) and for stringent voltage regulation requirements. Each section consists of 20 cells of 3-ampere-hour nominal capacity. Both sections are automatically activiated in 0.4 sec. by a single activation mechanism. Yardney Electric Corp., New York, N.Y.

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Stationary Magnet Clutch

Containing a stationary magnet, clutch has a torque rating of 45 lbs-ft and can be converted to a magnetically set brake by securing the rotor to the magnet body. Coils can be wound for voltages up to 115 volts dc max, and insulated with class "A" through class "H" insulation. Unit is also available in clutch-brake combinations. Stearns Electric Corp., Milwaukee, Wis.

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Resonant Circuit

Measuring less than 0.4 cu. in., 45 kc resonant circuits have applications in triggering and timing circuits. Three db bandwidth: 4500 cps max.; source impedance: 3000 ohms. Units from 20 kc to 100 kc are available. Control Electronics Co., Inc., Long Island, N.Y.

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Regulated Power Supplies

Automatically regulated over a wide range by a simple manual setting, a power supply is claimed the first to do so of any unit rated from 100 watts to 50 kw, ac or dc. No distortion in output and regulation is available from zero to any desired voltage. Visual scales give percent of accuracy as well as the voltage to which the regulator has been set. American Rectifier Corp., New York, N. Y.

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Mercury Switch

Low cost 2 amp mercury switch that is shockproof, waterproof and operates on any axis has a nominal diameter of 0.500" and a nominal length of 1 11/16". Both the switch and the leads are potted in rigid PVC for complete moisture protection. Gordos Corp., Bloomfield, N.J.

Write No. 409 in Box on Inquiry Card

Programmed Pulse Generator

Pulse generators produce accurate delay pulses and gating waveforms with pre-selected periods and pulse bursts quantized in time. Any distinct number of pulses may be pre-selected in any desired repetitive sequence. Typical applications are: computer development; date handling systems; simulation of radar and sonar range targets; delaying scope sweeps and system programming. Universal Data Systems, Valley Stream, L.I., N.Y.

Write No. 440 in Box on Inquiry Card

Magnetic Amplifier

Delivering one watt of dc power from microwatt signals, a low level magnetic amplifier has a power gain of 3,000,000 and requires no pre-amplification. Unit has a control winding sensitivity of three micro amps at 1000 power of 0.01 microwatt. The amplifiers require less than one cu. in. of ohms and a minimum control winding space when powered by 2000 cycle or higher frequency sources and somewhat larger size when lower frequencies are used. Polyphase Instrument Co., Bridgeport, Pa.

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THE MQ SERIES CRYSTAL-CAN-SIZE HERMETICALLY SEALED RELAY IS AVAILABLE IN THREE SENSITIVITIES TO MEET VARYING MILITARY AND INDUSTRIAL REQUIREMENTS. THESE CURRENT-OPERATED RELAYS COME WITH PLUG-IN PINS FOR PRINTED CIRCUIT USE, SOLDER HOOKS AND 3-INCH LEADS AND A VARIETY OF MOUNTING ARRANGEMENTS. ALL CONNECTIONS ARE SPACED ON 0.2 INCH GRID.

SPEC	MQA	MQB	MQC
Pull-in Power (@ 25°C)	250 MW	100 MW	50 MW
Contact Rating (Res @ 28VDC or 115VAC)	2 amps	1 amp	1 amp
Operating and Release Times	5 MS ea	6 MS ea	7 MS ea
Shock	50G	35G	20G

Contact Arrangement: DPDT
Temperature Range: −65°C to +125°C
Dimensions: 0.875 in. h x 0.800 in. w x 0.396 in. thk
Weight: 0.6 oz.
Life (at rated load): 100,000 operations minimum

ELGIN ADVANCE

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2435 N. Naomi St., Burbank, California
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NEW COMPONENTS

SCR Triggers

Intended for general purpose and experimental use in triggering silicon controlled rectifiers, single output and dual output magnetic triggers weigh, respectively, 8 oz and 12 oz, and measure, respectively, 2⅛" high by 1½" square, and 3 23/32" high by 1½" square. Among their main features are fast response, solid state reliability, three separate inputs, and an extended cut-off region. Ovitron Corp., Long Island City, N. Y.

Write No. 330 in Box on Inquiry Card

Temperature Compensation Resistor

Resistor's temperature coefficient, ranging from 10 ppm/°C to 4500 ppm/°C, can be adjusted externally with no affect on fixed resistance values. Units may be used to temperature compensate complete electronic circuits, printed circuit board modules or individual components such as solid state devices. Conrad-Carson, Inc., San Diego, Calif.

Write No. 332 in Box on Inquiry Card

Transformer Cases

Glass epoxy laminated cases eliminate metal cans or potting molds in encapsulating high temperature transformers. The case consists of two halves bonded together with the winding enclosed and filled with potting compound. This simplified procedure reduces steps in potting, reduces weight of the unit and eliminates rejects due to thin spots. Thin wall glass reinforced laminated cases are available in all temperature classes and are tooled for specific applications. Stevens Products, East Orange, N.J.

Write No. 501 in Box on Inquiry Card

Tension Fasterners

Having minimum static tensile strength of 16,000 psi and an endurance limit of 40,000 psi, standard tension fasteners fill a void in the fastener spectrum between standard aircraft and missile superbolts and the standard industrial fasteners. Typical applications include aircraft accessories; ground support equipment; critical pumps, turbines and electrical alternators; high speed machine tools and high-impact machinery. Standard Pressed Steel Co., Jenkintown, Pa.

Write No. 507 in Box on Inquiry Card

Pressure Regulators

Called the Vernator, a vernier pressure regulator precisely regulates pressures in non-flow pneumatic systems over the range of 0.1 to 1000 psi, while maintaining actuating forces at a low level. Units are especially useful for calibrating and checking pressure instruments including deadweight testers. Astromics Corp., Glendale, Calif.

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Transfer Volt Ammeter

Ammeters measure voltages between 0.5 and 1500v and currents between 7.5 ma and 25 amps within 0.5% accuracy at frequencies from 5 to 50,000 cycles. Units contain plug-in accessories which enable highly precise measurements at frequencies up to 30 Mc. Designed to meet increasing demands for accuracy, the unit contains a thermal converter that equates the heating effect of the unknown current to that of a known current. A null galvanometer establishes the point of equality; a potentiometer then measures the direct current, against which the unknown value has been related. Engelhard Industries, Inc., New York, N. Y.

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CIRCLE NO. 53 ON INQUIRY CARD

Sub-Miniature Capacitor

Dipped silvered mica capacitor is said to retain the desirable performance features and superior electrical characteristics found in much larger silvered mica capacitors. Approximately 5/16-in. long ¼-in. wide and ⅛-in. thick, the capacitor is made with parallel leads for greater versatility and is encased in specially treated phenolic as a protection against physical damage and the penetration of moisture. The unit is said to be ideally suited for printed circuit applications. Electro Motive Mfg. Co., Inc., Willimatic, Conn.

Write No. 690 in Box on Inquiry Card

Induction Motor

High rotor impedance servo motor characterized by a linear-torque versus speed curve is said to have an unusually high torque-to-inertia ratio which provides fast acceleration. Measuring 1.5 in. in diameter and 1.5 in. in length, the motor has a minimum no-load speed of 6500 rpm. Unit operates at 115 v with maximum power input of 8.5 w. Acceleration is 88,000 rad/sec^2; torque at stall, 1.25 oz-in.; torque^2 inertia is 110,000 oz-in./sec^2. Koilsman Motor Corp., Dublin, Pa.

Write No. 691 in Box on Inquiry Card

Ceramic Switches

Specially developed high-temperature alloys and new assembly techniques assure that miniature switches will withstand temperatures to 175 C. Frequently eliminating an entire switch section, the units provide up to 22 terminals per section, each terminal insulated from the other. Centralab, Milwaukee, Wis.

Write No. 421 in Box on Inquiry Card

Nylon Fasteners

Plastic wire ties combine strength, durability, and simplicity of application in bundling groups of wire and similar harness applications. The ties are easily removed to speed repair, or to add more wires without disturbing the tie or the group of wires. Breaking points range from 45-95 lbs. Nylon cable clamps are light weight and chemically resistant combining toughness and shock resistance. They are effective at a temperature range of +300 to −60F. Also, a low-priced nylon hex machine screw nut is offered in a variety of sizes. Nut is double shamfered and double countersunk for automatic feeding. Nylogrip Products, Boston, Mass.

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Rotary Trimmer

Capable of withstanding at least 150 G shock and 15 G vibration, miniature, single turn rotary trimmers come in a solid metal case with molded-in rear terminals or leads as well as an "O" ring shaft seal. Power rating: 2 watts at 60 C; standard resistance: 10 ohms to 20 K; resistances available to 150 K on special order. All electrical connections of the 1/2 in. dia. trimmer are welded; all moving contacts consist of solid precious metal. International Resistance Company, Phila., Pa.

Write No. 310 in Box on Inquiry Card

Silicon Diodes

Rated for 150 m power dissipation, fused (alloyed) junction diodes, consist of: zener diodes, general purpose diodes and double anode (twin zener) diodes. Typical applications include: voltage regulation, voltage limiting in control circuits for ac to dc amplifiers and surge protection. Hermetically sealed, these diodes withstand temperatures from −65 to 175 C and mount in any position. Controls Co. of America, Tempo, Ariz.

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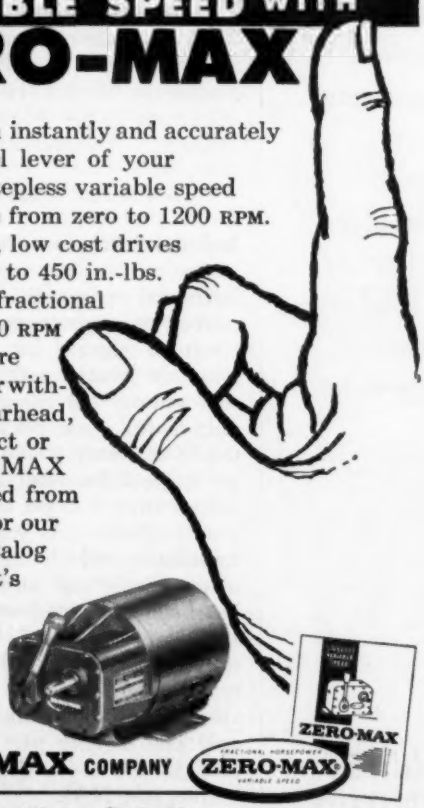

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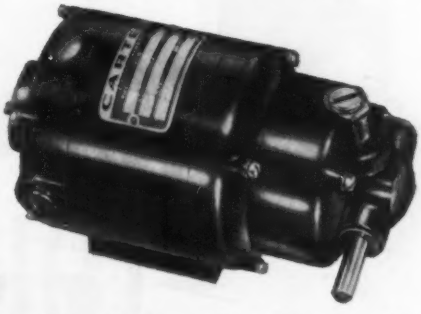

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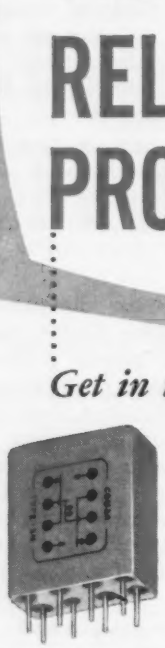

SUB-MINIATURE

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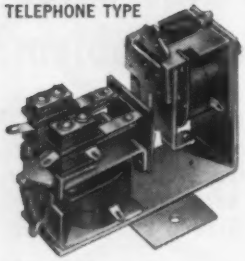

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NEW COMPONENTS

Radiant Energy Standards

For precision calibration of infrared radiometric instruments, six highly-stable, black body, radiant energy sources come in temperature ranges from 50 to 1000C; from 200 to 600C; and from 325 to 1000C. A unique electronic closed-loop temperature control insures temperature stability of 1 degree at any temperature, regardless of ambient temperature changes, line voltage variations, or component aging. The entire control loop consists of a platinum temperature sensor in the black body and an all solid state controller, designed especially for these black bodies. Infrared Industries, Inc., Waltham, Mass.

Write No. 327 in Box on Inquiry Card

Unijunction Transistors

Three silicon unijunction transistors are designed, characterized and priced for solid state relay, triggering and switching circuits in industrial electronic equipment. Type 2N1671 is intended for general purpose industrial use where circuit economy is of primary importance. Type 2N1671A is for use in firing circuits for silicon controlled rectifiers and other applications where a guaranteed minimum pulse amplitude is required. Type 2N1671B is used where a low emitter leakage current and a low trigger current are required. All of the new unijunction types have a maximum intrinsic standoff ratio of 0.62; interbase resistance characteristics are minimum of 4.7 kilohms and a maximum of 9.1 kilohms at 25 C; minimum valley point currents are 8 milliamps. General Electric Co., Syracuse, N. Y.

Write No. 708 in Box on Inquiry Card

Industrial Pressure Transducers

Industrial pressure transducers that convert fluid pressures into continuous electrical signals for directly driving remotely located milliammeters or direct-writing galvanometers are available in full scale pressure ranges from 0-1.5" of water (0-0.05 psi) to 0-5000 psi gage, differential and ±. Absolute ranges from 0-5 psi to 0-5000 psi are also available. A variable reluctance transducer, which has been used in many missile and aircraft applications, has been combined with transistorized circuitry to provide a rugged and stable industrial transducer. Diaphragm type design features high shock and vibration characteristics, long life, and only one moving part. No wipers and linkages are used. Ultradyne, Inc., Albuquerque, N.M.

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LETTERS

(Continued from page 8)

to-balance method will quite frequently prove preferable to the table testing method.

In answer to your comment on measurement of compliance effects we should point out that MIT and others have been using the torque-to-balance method to determine compliance effects for several years. This is accomplished by rotating the gyro input axis in a plane perpendicular to the polar axis and measuring the required torque to balance. As you can imagine the required turn-table for this application is extremely simple in comparison to the servo driven turn-table with accurate pick-off necessary in the slave table method of measuring. This type of measurement was not discussed in the article since the gyro test equipment considered there was specifically designed for testing of the 25 IRIG gyro. The test specification for that gyro as written by the MIT Instrumentation Laboratory does not involve a tumbling test and therefore does not measure the compliance parameters of the gyro.

Your listing of the errors in the gyro test console is quite correct. The most important of these errors is the a-c power supply drift. This unit has been measured to have a short term stability of about 0.03%. Thus, out of one earth rate, the unit is capable of measuring down to 6/10 meru. Whether or not this is sufficient depends on the gyro characteristics and the length of averaging time that can be tolerated, since if the allowed averaging time is short, the errors in the turn table method of testing become excessive. If the gyro is mounted with its input axis east then the errors due to the a-c power supply drift are only a percentage of the total drift of the gyro. It is therefore possible in many cases to measure down to 0.001 degrees per hour or better. In the case of turn-table testing, however, you are still faced with the absolute accuracy of the pick-off itself.

You comment that a peak reading position error of ½ sec. arc. has been obtained using the glass disc pick-off system. We know of no such unit commercially available. More typical numbers are of the order of 5 sec. of arc. Should you have such a unit, we would be most interested in obtaining literature describing it.

Closer observation of Figure 6 of the article will reveal that the damping feedback path mentioned is shown there. In the steady state there is no current in this path. The only current appearing are high frequency transients (compared with a 20 second loop). Thus, the feedback path contributes no appreciable error to the system since the loop is designed to provide a certain amount of filtering.

Summarizing, it may be said that the torque-to-balance method can be as accurate as the turn-table method when the gyro itself is taken into account. That is, in a very large number of cases there will be no observable difference between the measurements made by either method. Deciding which method to use may then be based strictly on economic considerations.

We do not imply, however, that the torque-to-balance method is superior to the turn-table method in all conceivable cases. Nor, may we point out, is the reverse true. It is necessary here, as always, to consider the test instrumentation as a part of an overall system problem rather than as an isolated element. When this is done a great deal of effort, time and money can be saved.

A. L. Friedman
Technical Director
Dynamic Research Corp.

WORTH FILING

Insulating Materials

For reference information on high-temperature insulation materials, a revised, up-to-date engineering comparison chart details the commonly-used plastic and ceramic insulating materials, including the various formulations of ceramoplastics and glass-bonded mica. The leaflet lists temperature limits for 88 materials and thermal expansion coeffiecients of 57 widely used insert metals and insulating materials.

Source: Mycalex Corporation of America
Clifton, N. J.

For Your Copy: Write No. 846 on Inquiry Card

Fluorescent Compounds

As a guide to dientifying solutions through their fluorescent properties, a 19-page booklet lists characteristics of several hundred fluorescent compounds. Also included are activation and fluorescing wavelengths, pH values, and ultimate sensitivities. A bibliography of about 40 fluorometry papers describes a wide range of research projects.

Source: American Instrument Co., Inc.
Silver Spring, Md.

For Your Copy: Write No. 847 on Inquiry Card

"I don't think we should mention testing in that contract, J. J. We've found that test programs tend to show up faults years before the mistakes will be discovered in the field."

For Your Literature File

NEW CATALOGS

Most of these catalogs contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the catalogs listed on this page, enter the appropriate number of the item on the Inquiry Card.

Magnetic Amplifiers 959

Characteristic curves, photos, and circuit diagrams are used to illustrate how to avoid design compromises with magnetic amplifiers. A custom designed three-phase magnetic amplifier, a static exiter, and other basic types of magnetic amplifiers match the characteristics of associated circuits. (4 pp.) Polyphase Instrument Co., Bridgeport, Pa.

Armature Relays 972

Valuable engineering data on important phases of relay performance are given along with descriptions of balanced rotary armature relays (header and enclosure styles.) Information on electronic time delays, solid state moduls and voltage sensors is also included. Hi-G, Inc., Windsor Locks, Conn.

Photoelectric Controls 973

Described are some of the latest deveopments in high speed, ultra sensitive and impulse-actuated controls; photoelectric and electronic timing controls; controls with built-in sensing heads and miniature remote sensing heads. Wide selection of light source also covered. (24 pp.) Autotron, Inc., Danville, Ill.

Ceramic-To-Metal Sealing 990

An iron-nickel-cobalt alloy, called Ceramiseal, has expansion characteristics closely matching those of high temperature alumina ceramics. Also, Ceramiseal has a low thermal conductivity which approximates that of ceramics. Booklet describes how the sealing alloy minimizes thermal stresses during rapid heating and cooling cycles. (4 pp) Wilbur B. Driver Co., Newark, N. J.

Bimetal Thermal Switches 989

Brochure contains a discussion of the bimetal principle and gives detailed technical information on applications, specifications, standard variations, and modifications of eleven bimetal thermal switches. All switches conform to government standards and military specs. (8 pp.) Control Products, Inc., East Hanover, N. J.

Power Conversion 993

Applications of solid state and magnetic devices to power conversion are discussed. Equipment includes solid state sine wave inverters; low and high voltage transistor regulated power supplies; modular power supplies; and five different solid state power converters for special application. (8 pp) Power Sources, Inc., Burlington, Mass.

Proximity Switches 957

Basic technical information enables prospective users to determine the proximity switch best suited for particular needs. The switches' sensing heads are actuated by all metals — both magnetic and non-magnetic — without physical contact. Booklet features a control amplifier selection guide, which facilitates matching of control amplifiers to specific applications. A new proximity switch, said to be the lowest priced true proximity detection devcie on the market, is fully described. (7 pp) Electro Products Labs., Inc., Chicago, Ill.

Servo Motors 961

Used with transistorized amplifiers, off-the-shelf reversible induction motors, 115 v, 60 cycles, have typical rating of 0.75 oz. In. at 1000 rpm; gear reductions range from 5:1 to 3600:1. Control windings are split into two sections, each having an impedance of 16 ohms and separate leads. Can be used in push-pull circuits. National Pneumatic Co., Inc., Boston, Mass.

Wire-Wound Resistors 974

Performance characteristics of encapsulated and bobbin type wirewound resistors with standard tolerance of ±1% and special tolerances as slow as 1/20% are given. Also described are microminiature units designed specifically for printed-wiring applications. (20 pp.) Aerovox Corp., Burbank, Calif.

Solid State Electric Controls 975

Designed to produce process variable outputs in accordance with desired or set point conditions, a combination of electrically and electronically operated devices uses such primary measuring elements as thermocouples, stain gages, resistance temperature detectors or moveable core transformers. Measuring signals are transmitted through control signal manipulators to either electrically-operated control or pneumatically-operated control drives or valves. (4pp.) Bailey Meter Co., Cleveland, Ohio.

Semiconductor 951

Breakdown voltage, current capacity operating temperatures and power dissipation are given for germanium power transistors, audio and switching transistors, silicon and germanium mesa transistors, silicon rectifiers, and silicon zener diodes. Included is information on a reliability program which makes "military equivalent" semi-conductor devices available commercially (12 pp.) Motorola Semi-conductor Products, Inc., Phoenix, Ariz.

Silicon Rectifiers 992

Detailed data on more than 80 silicon power rectifier units with a range of 50 to 600 volts PIV, and ½ through 400 amps are given. The Vari-Stack, a recently developed universal silicon diode assembly, is also covered. (16 pp) Rectifier Corp., Santa Ana, Calif.

Relay Potentiometer 986

Designed to replace relays, switches, and potentiometers for low-noise commutation, switching and controlling circuits, an electro-optical relay potentiometer can be used as a control link in either the tube or transistor version of the AGC loop; suppressed carrier modulator; single-pole, double-throw relay; commutator; or negative resistance generator. Brochure explains performance characteristics and how the basic circuit component fits various circuit configurations. Raytheon Co., Newton, Mass.

Cable Connectors 985

Isolated ground, coaxial cable connectors are said to provide absolute protection from circulating currents and ground loops that cause oscillation and faulty readings of current and voltage. A concentric, three-element, glass-to-metal seal provides a hermetically sealed isolated ground without shoulder washers and other insulating or mounting devices. The brochure lists the fittings and gives full technical specs. (4 pp) Dage Electric Co., Inc., Beech Grove, Ind.

Gear and Pinions 963

Zinc die cast, one-piece gear and pinions can solve transmission problems involving small, light-load gearing. Pitch, number of teeth, and pitch diameter are described for: gear and hub with hole, gear and pinion with hole or shaft, flanged pinion with hole or shaft and many other combinations. (10 pp.) Gries Reproducer Corp., New Rochelle, N. Y.

Precision Resistors 958

Complete line of vitreous enamel and precision wire-wound resistors are available in a wide variety of standard designs and ratings. Resistance values and tolerances may be varied to meet individual specs. Selection guides and tables of specs are given. (12 pp.) Precision, Inc., Minneapolis, Minn.

Tantalum Foil Capacitors 952

Expanded line of plain and etched tantalum foil electrolytic capacitors now includes all five case sizes listed in Mil-C-3965B for styles CL24, CL25, CL34, and CL35. Bulletin contains scale that simplifies conversion from "equivalent series resistance" to "power factor" or "dissipation factor" or vice versa. (4 pp.) Ohmite Mfg. Co., Skokie, Ill.

Panel Meters 953

Ninety-two standard models of voltmeters, ammeters, milliammeters, and microammeters in three sizes, 2½ in., 3½ in. and 4½ in. feature 2% full scale accuracy for dc models and 3% accuracy for ac units. Modifications available are zero adjusters, special dials, special ±1% calibration at a specific temperature, ±1% at any point, and ±0.5% full scale value. Data tables include meter sensitivity, standard coil resistance and standard voltage drop. (4 pp.) Helipot Div., Beckman Instr., Inc., Fullerton, Calif.

Relays 950

Lists hundreds of "off the shelf" relays such as sensitive, power, antenna, microminiature, hermetically sealed, telephone and multi-pole sensitive types. (8 pp.) Kurman Electric Co., Brooklyn, N. Y.

Mass Spectrometer 979

Designed for advanced-materials research, a modular constructed spectrometer is said to employ a mass-resolving system more powerful than that of other commercial units. The spectrometer analyzes metals and other solids, separates dissimilar molecules of the same nominal mass, analyzes heavy organic compounds, and permits structural identifications through precise mass-number measurements. (8 pp.) Consolidated Electrodynamics Corp., Pasadena, Calif.

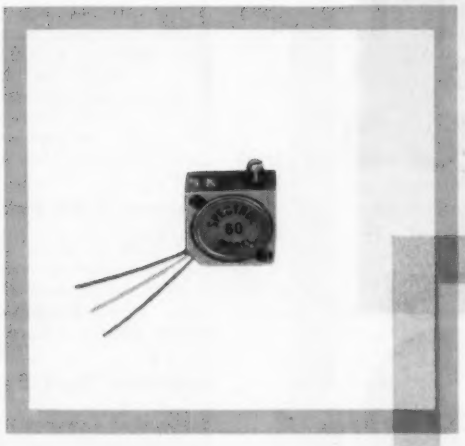
Electromagnetic Drives 977

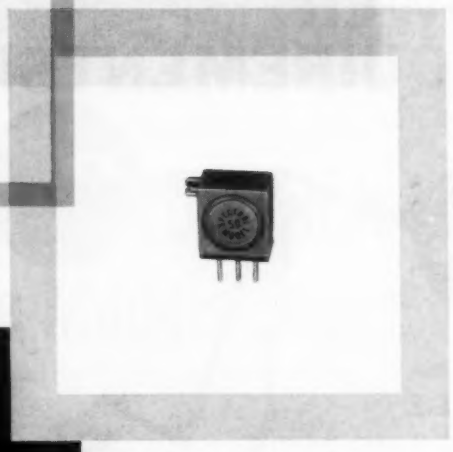
How electromagnetic drives work, what they include and where they are used are covered along with descriptions of various types such as: air-cooled, "magnaflow" drives and liquid cooled units. Associated with each type, the excitation system, optional operating functions and mechanical features are reported in detail. (12 pp.) Westinghouse Electric Corp., Pittsburgh, Pa.

Digital Voltmeters 976

Two bulletins on digital voltmeters are available, one covers a low cost industrial unit, the other describes a high accuracy all-electronic digital voltmeter. The industrial unit is said to be the first four-digit instrument to offer plug-in stepping switches, printer connections and automatic print control for less than $2500. (10 pp.) Non-Linear Systems, Inc., Del Mar, Calif.

Go Ahead, TRIM SQUARE





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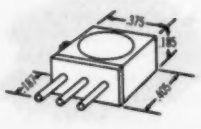
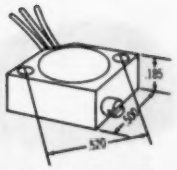


THE MODEL 50
3/8" square, 3/16" high, and weighing 1 gram, the Model 50 is available in standard resistances of 50 ohms to 20K ohms.



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1/2" square, 3/16" high, and weighing 2 grams, the Model 60 is available in standard resistances of 50 ohms to 50K ohms.

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Stack 'em . . . up to 35 Model 50 trimmers in one cubic inch. Adjust 'em, 25 turns for full electrical travel . . . take your choice of side or top adjustment, slotted fillister head screw, Allen hex socket, or slotted headless screw flush mounted. Dissipates 1 watt—Model 50 and 2 watts—Model 60. Dual wiper provides double assurance of positive contact under all conditions. High resolution, typically 0.061% for the 50K ohms model. Resistance tolerance, ±5%, temperature range, −55 to +150° C.

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NEW CATALOGS

All-Metal Seal 960

A seal with one-piece construction and a cross section that resembles an 'X' seals at temperatures −450 to +1200 F and withstands pressures of 40,000 psi. It is used in supersonic aircraft, armament mechanisms, missile flight control systems, space craft actuators and in most critical environments. (4 pp) E. B. Wiggins Oil Tool Co., Los Angeles, Calif.

Vacuum Tube Reliability 980

Four page brochure describes the value of Thermions (thermal analogs of vacuum tubes) in determining thermal reliability for vacuum tubes. Tube equivalence chart included. (4 pp) Rescon Electronics Corp., Waltham, Mass.

Universal Gear Box 981

Designed as a developmental speed reducer and increaser, with 10 basic ratios (5 reductions and 5 increases), a universal gearbox eliminates the need for a number of single ratio units. Standardized mounting dimensions insure quick and accurate assembly with all hangers, breadboard plates and development components. No tools or critical adjustments are necessary when changing ratios, as the box is simply placed in the correct position for the ratio desired. (6 pp.) PIC Design Corp., East Rockaway, N. Y.

Power Supplies 982

Engineering details of nine wide-range, transistorized power supplies and five transient suppressed, high-current, magnetically regulated power supplies are given. Included are applications, specs, outline drawings, impedence curves, and operational and special features. (12 pp) Magnetic Research Corp., Hawthorne, Cal.

DC Power Modules 983

Contained in a brochure which describes transistorized modular power supplies is a quick selector chart for rapid selection of outputs required, with a key to the module that will satisfy the requirements. Thirty-seven models, all of which have been packaged to permit proper dissipation of heat and fast replacement of components, provide voltage outputs from 0.5 to 100 and current outputs from 75 to 750 ma. (4 pp) Dressen-Barnes Corp., Pasadena, Cal.

Metal Sheathed Thermocouples 984

Technical advantages made possible by metal sheathed thermocouples and applications where they have proved most effective and economical are listed. Also examined are standard junctions, special junctions, standard cold end terminations and configurations. (4 pp) Harco Laboratories, Inc., New Haven, Conn.

Spring Fasteners 995

Information on standard and special spring fasteners in twin-prong or cone type impressions and push-on types includes tensile, torque and other design data. Arrangement of data facilitates the selection of fastener by style, screw or stud size. (13 pp) George K. Garrett Co., Inc., Philadelphia, Pa.

Spherical Bearings 962

Lined with Teflon, self-aligning bearings withstand loads up to 60,000 psi. They are said to provide the advantages of high load ratings and simplicity of assembly with long wearing low friction, self-lubrication, and high impact. (6 pp) Heim Co., Fairfield, Conn.

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WORTH FILING

Wire Construction

24 page wire component and assembly manual features case histories on the use of wire and strip metal components. Also described are principal types of wire for component construction, the most popular finishes, wire sizes and the variety of end treatments, threading and forming treatments possible.

Source: E. H. Titchener & Co.
Binghamton, N.Y.

For Your Copy: Write No. 832 in Box on Inquiry Card

Magnetic Alloys

Sixteen page technical discussion gives detailed background on a special alloy called Moly Permalloy, which is a combination of nickel, iron and molybdenum. Included in the booklet is information on testing data, magnetization curves, core loss graphs, typical physical, mechanical and magnetic properties, as well as other data.

Source: Allegheny Ludlum Steel Corp.
Pittsburgh, Pa.

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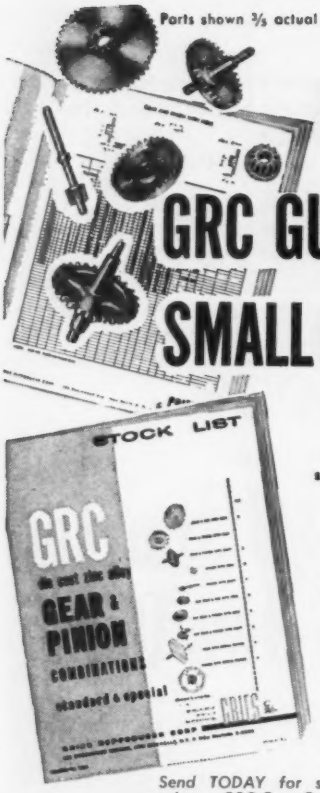

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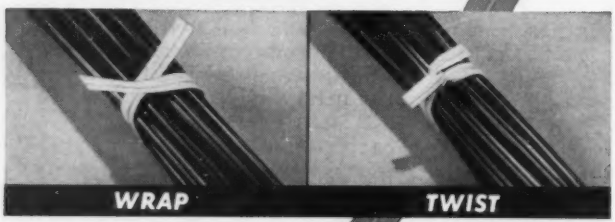

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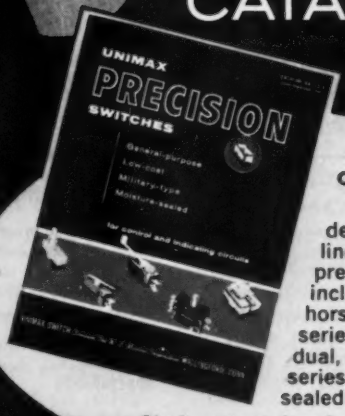
Zero-Max Co., The	81

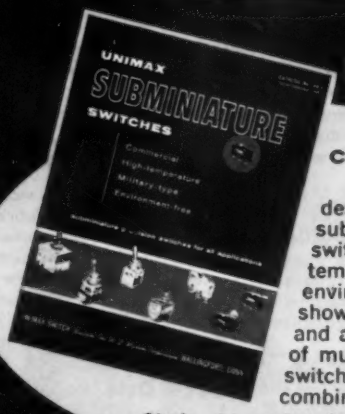
3 NEW UNIMAX SWITCH CATALOGS



PRECISION

CATALOG 10-1
describes complete line of phenolic-cased precision switches, including the new, horsepower-rated 2HL series, the new, dual, low-cost DA series, and three new sealed series.

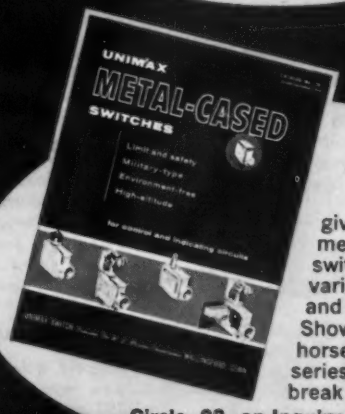
Circle 60 on Inquiry Card



SUBMINIATURE

CATALOG 20-1
describes subminiature switches, including high-temperature, sealed, and environment-free styles; shows 5 terminal styles, and a wide variety of multiple-switch/actuator combinations.

Circle 61 on Inquiry Card



METAL-CASED

CATALOG 30-1
gives details of metal-cased limit switches, with a variety of actuators and housings. Shows new, horsepower-rated KL series and double-break BK switch.

Circle 62 on Inquiry Card

Each catalog includes a useful section telling how to choose the proper switch for the service required; also photographs, dimensioned drawings and force and movement specifications for all switches. *Ask us for the catalog you need; it's free on request to*

UNIMAX SWITCH
Division, The W. L. Maxson Corporation
IVES ROAD, WALLINGFORD, CONNECTICUT

For Your 3-Ring Binder
NEW DATA SHEETS

Most of these data sheets contain complete specs, mounting configurations and other important details associated with the application of the products described. For your free copy of the data sheets listed on this page, enter the appropriate number of the item on the Inquiry Card.

Pressure Transducers 938

Capable of absolute and gage measurements to 10,000 psi, strain gage transducers operate without damage at temperatures from −320 to +300F and provide an output of 40 mv; they can be used in a 1000-g environment. Provision is made for external adjustment of bridge balance, temperature compensation and sensitivity. Consolidated Electrodynamics Corp., Pasadena, Calif.

Transistorized Amplifiers 939

Miniature, solid state amplifiers are employed with piezoelectric accelerometers to study missile and airborne shock and vibrations. Twelve off-the-shelf models are described including emitter-follower amplifiers, wide temperature amplifiers, high gain accelerometer-amplifiers and self-amplifying accelerometer systems. Columbia Research Labs., Woodlyne, Pa.

Subminiature Switch 940

Highly sensitive switch serves where close control sensitivity or response is mandatory. Differential travel of 0.001 inch makes the switch ideal for temperature or pressure control in military and industrial applications. Micro Switch, Freeport, Ill.

Control Mechanisms 941

Infinite-positioning, self-locking, irreversible control mechanisms offer numerous applications in every phase of industry including flight controls, stationary and marine engines and hydraulic valve controls. They are applicable wherever there's a requirement for vibration-proof controls, with quick, positive, wide-range settings. The mechanism has five main elements: a primary handle or driving lever, an actuating or driven lever, two locking shoe assemblies, and a stationary quadrant. Adams-Rite Mfg. Co., Glendale, Calif.

Filter Assemblies 942

Stainless steel element-in-line filter assembles offer the optimum combination of: high efficiency of particle removal, high dirt capacity, low pressure drop, controlled absolute cut-off and cleanable elements. Units are especially useful where space limitations preclude use of "T"-type assemblies and in "one-shot" installation where disassembly is not anticipated. Twenty data sheets show a cross-sectioned view of filter elements and housings. Aircraft Porous Media, Inc., Glen Cove, N.Y.

Thermocouple Harnesses 943

Technique of grouping wire leads of individual thermocouples into stainless steel covered, flexible harness assemblies makes possible several important advantages of economy and performance in thermocouple thermometry. Installation and removal time are reduced: storage is facilitated; wear and tear through handling diminishes; failure of individual thermocouples does not impair an assembly's function. Harco Labs, Inc., New Haven, Conn.

Diallyl Phthalates 913

Comprehensive chart, listing electrical, structural, thermal and other data, is said to represent the first tabulation of all variations of regular and flame retardant Diallyl Phthalates plastics. Mil specs are also listed. Mesa Plastics Co., Los Angeles, Calif.

Rectifiers 914

Diodes, meter protectors, varistors, modulators, phase comparators, and what is said to be the smallest instrument rectifier available are described. Copper oxide rectifiers are stabilized to prevent permanent changes with temperature variations. Vacuum processed with gold contacts, rectifier cells produce minimum contact resistance with no oxidation. Edal Industries, Inc., East Haven, Conn.

Solid Film Lubricant 907

Containing a molybdenum disulfide compound, a solid film lubricant designed for most types of metallic surfaces prevents galling, seizing, fretting, corrosion, cold welding and similar friction problems over a wide range of pressures, temperatures and surface speeds. The material air drys in 15 to 20 minutes. Hohman Plating & Mfg., Inc., Dayton, Ohio.

Data Recorders 925

Portable, direct-writing recording system contains two channels for analog data plus two for coded data written on a common time base. The ink or electric writing recorders are reported to offer flexible easy operation and sensitive built-in amplifiers. Brush Instr., Cleveland, Ohio.

Level Mounds 923

Supporting loads up to 30,000 lbs per mount, pneumatic mounts maintain levels better than two sec. of arc or 50 millionths in. per ft. Isolates high precision machines from floor-borne vibrations. Barry Controls, Inc., Watertown, Massachusetts.

DC to DC Current Monitors 924

Completely isolated from current carrying conductors, monitors measure bus current flow up to 250 amps with accuracy to 0.2%. Output regulates current sources or acts as overload protection for circuits. Fully encapsulated and hermetically sealed, units meet Mil-E-5272C. Arnold Magnetics Corp., Los Angeles, Calif.

Induction Potentiometer Transducers 928

No sliding or wearing parts, temperature errors of less than 0.01% per degree F within the range −65 to +275F., and a combined linearity, hysteresis, friction and repeatability error of less than +1.0% characterize ac pressure instruments. Units are available for absolute, gage and differential pressure measurements in ranges between 0-600 and 0-20,000 psi. Servonic Instruments, Inc., Costa Mesa, Cal.

Frequency-To-Analog Converter 931

Designed to match the accuracy of advanced instruments, converter offers 0.1% accuracy at up to 10 kc, and variable and selectable time constants. Two channel and one channel models are available. A 10 volt output for one model is provided by a modular dc amplifier. Second model is rated 1v. Potter Aeronautical, Union, N. J.

Incremental Digital Encoders 932

Encoders based on a versatile optical design for digital servos, numerical control systems, integrating accelerometers and inertial platforms are described in 4 data sheets. Dynamic Research Corp., Stoneham, Mass.

Dynamic Focus Coil 933

Optimum alignment is achieved by combining static and dynamic coils into single unit. The dynamic focus coil provides sharp overall focusing for flat faced large angle cathode ray tubes of 1½" neck diameter. Circuits can be simplified and power saved because double gap design isolates the coils from each other. Increased efficiency at high frequencies is obtained by coil's core material and design. Efficient heat dissipation permits use up to 25 kv accelerating potential. Syntronic Instruments, Inc., Addison, Ill.

Silicon Diodes 934

The configurations of diffused Zener diodes, double anode (twin Zener) diodes, and general purpose diodes make production assembly methods possible in terminal strips, plug-in, and clip-in mounting arrangements. In addition to printed circuit applications, the units are also designed for standard subminiature light bulb sockets and are used for blocking in dc circuits. Controls Co. of America, Tempe, Ariz.

DC To Sine Wave Inverter 935

From a 28-volt battery source, a fully transistorized, solid state inverter converts dc to pure sine wave 400 cycle power, and delivers up to 55 volt-amperes with less than 2% total harmonic distortion. Circuit design renders the model insensitive to widely varying temperatures, load impedence, and power factor. Unit is fully protected against short circuits, line spikes, and polarity reversals. Completely encapsulated and hermetically sealed, the inverter meets the requirements of Mil-E-5272C for moisture, shock and vibration. Arnold Magnetics Corp., Los Angeles, Calif.

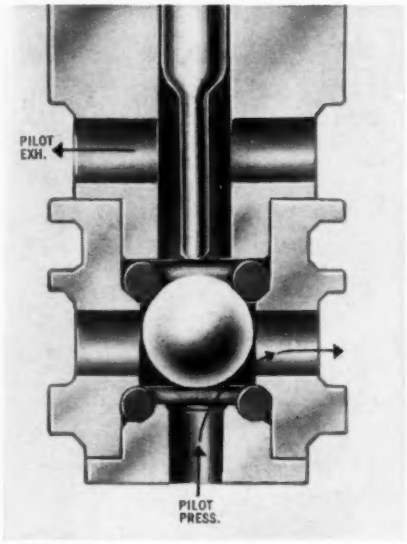
Hydraulic Oils 936

Eleven straight distilled oils with viscosities ranging from 55 SUS at 100 F to 140 SUS at 210 F are recommended: for hydraulic and circulating systems operating below 120 F, where oil is constantly being replaced because of leakage, or where filters are used to remove contamination and recondition the oils for extended use. These oils are also recommended for once-through application to plain bearings. Sun Oil Co., Philadelphia, Pa.

Power Resistors 900

For use wherever low-cost, easily-installed resistors are needed, high-temperature units which feature fireproof inorganic construction come in ratings of 3, 5, 7, 10, 15 and 20 watts. Resistance elements are uniformly and tightly wound on glass fibre cores. Tinned copper leads are secured to the element; the element-lead assembly is sealed in a rectangular ceramic case providing a mechanical protective bond between the resistance element, terminals and case. International Resistance Co., Philadelphia, Pa.

How To Build An Air Valve That Beats Friction and Coil Heat



ENLARGED SECTION OF PILOT CARTRIDGE

To Achieve Endurance, a Breakthrough in Speed

Generally, the most unpredictable factor in solenoid valve life is the solenoid coil itself, and yet, a solenoid can be made to last practically forever if the coil can be kept from overheating. Coil heat is generated by long plunger travel and accelerated by erratic drag (friction) during that travel. Achieve a short, quick, sure plunger stroke and the coil will last indefinitely. Therefore, the life of a solenoid pilot air valve is directly related to speed of operation. To achieve operating speed, friction in the pilot section and solenoid plunger travel must be reduced to a minimum. Solve these problems and you get air control reliability that seems to have no limit.

The Call-Outs Tell the Story of Endurance

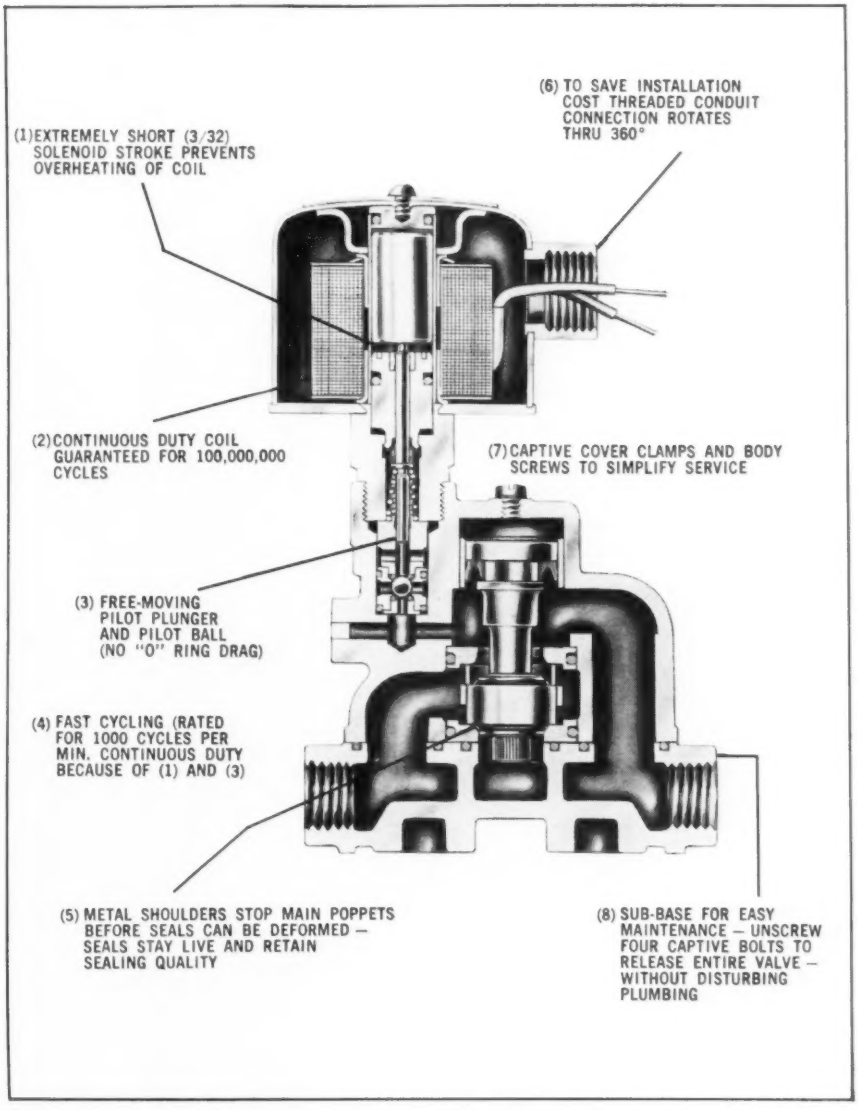
To control the major source of coil burnout, coil heating, the stroke of the solenoid plunger must be reduced to a minimum. The short stroke fractions the time the coil is energized; heat generation drops and response time of the valve is stepped up. In the "Mach 2" the stroke has been reduced to 3/32—about the thickness of a nickel. Furthermore, the friction problem must be solved, to avoid any unpredictable drag. In the "Mach 2" this has been done by use of a pilot cartridge enclosing a free-moving ball that seats on "O" rings at both ends of the cartridge [see above]. The ball moves freely, independent of the seals. There is no "O" ring drag on the pilot plunger as it requires no seals. When there is no friction there is no wear. Similarly, the main valve seats seal on "O" rings. In the sealed position, metal shoulders take the shock in such a way that the "O" ring seal is merely kissed by the main valve seat [see (5) below]. As the rings are only minutely flexed they do not fatigue or lose their resilience.

What about Cycling Speed?

Short solenoid plunger stroke and elimination of friction make extremely fast cycling feasible. After exhaustive testing in the laboratory and on industrial applications for over six years the "Mach 2" is rated at 1000 cycles per minute continuous duty. Cycling speeds as high as 2100 have been successfully reached for intermittent periods of twenty minutes. During a two-hour test at a sustained speed of over 1500 cycles per minute the coil temperature stabilized at 7°C below the maximum code limit for Class A coils.

100-Million-Cycle Guarantee on Solenoid Coils

The design advances incorporated in the CRESCENT® "Mach 2" Air Valve are a significant breakthrough in both cycling speed and operating dependability. Put CRESCENT® "Mach 2's" (¼- to ¾-inch pipe sizes) on your "valve killer" jobs and see how freedom from coil burnout helps to cut operating costs. Write for an advance copy of the new CRESCENT® "Mach 2" catalog to Barksdale Valves, 5125 Alcoa Avenue, Los Angeles 58, Calif.


(1) EXTREMELY SHORT (3/32) SOLENOID STROKE PREVENTS OVERHEATING OF COIL
(2) CONTINUOUS DUTY COIL GUARANTEED FOR 100,000,000 CYCLES
(3) FREE-MOVING PILOT PLUNGER AND PILOT BALL (NO "O" RING DRAG)
(4) FAST CYCLING (RATED FOR 1000 CYCLES PER MIN. CONTINUOUS DUTY BECAUSE OF (1) AND (3)
(5) METAL SHOULDERS STOP MAIN POPPETS BEFORE SEALS CAN BE DEFORMED — SEALS STAY LIVE AND RETAIN SEALING QUALITY
(6) TO SAVE INSTALLATION COST THREADED CONDUIT CONNECTION ROTATES THRU 360°
(7) CAPTIVE COVER CLAMPS AND BODY SCREWS TO SIMPLIFY SERVICE
(8) SUB-BASE FOR EASY MAINTENANCE — UNSCREW FOUR CAPTIVE BOLTS TO RELEASE ENTIRE VALVE — WITHOUT DISTURBING PLUMBING

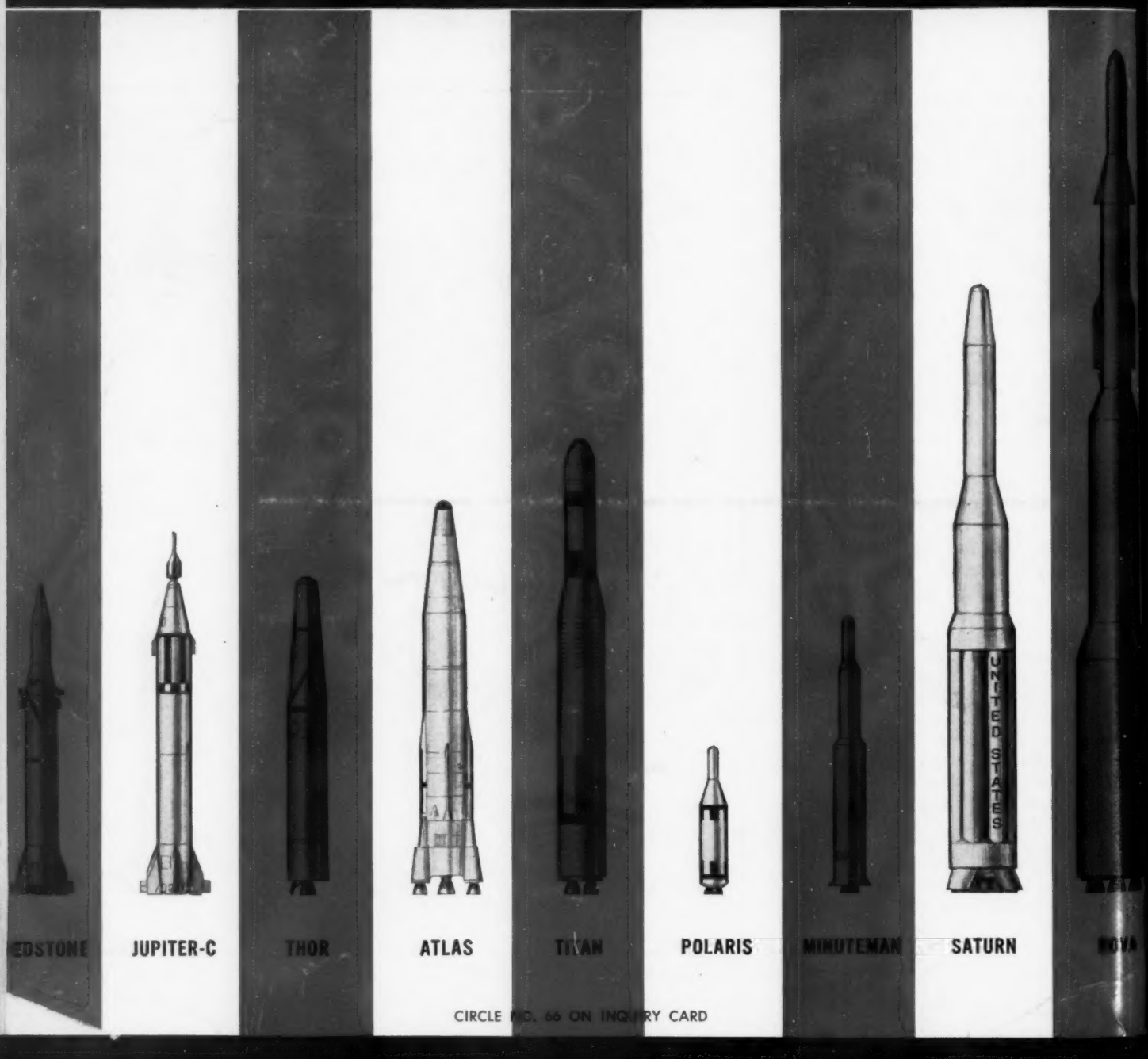
CIRCLE NO. 67 ON INQUIRY CARD

cppc's design and manufacture of critical guidance and control components, systems and computers for the Nation's defense, renders us totally involved in America's future.

We are not dissatisfied with this arrangement.

We believe America is going to meet its many challenges. We are working to meet ours—in the fields of RELIABILITY, QUALITY, ACCURACY.

CLIFTON PRECISION PRODUCTS CO., INC. · Clifton Heights, Pa.



CIRCLE NO. 66 ON INQUIRY CARD